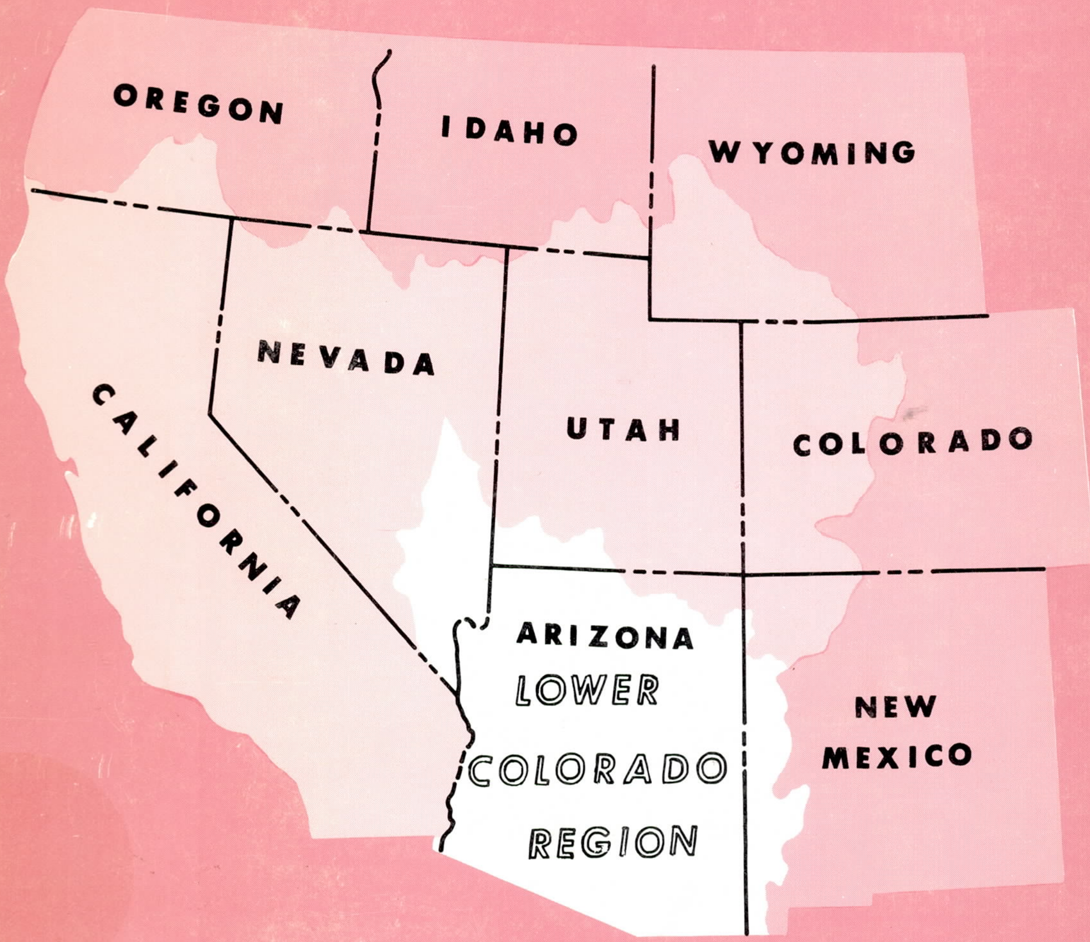
LOWER COLORADO REGION
Comprehensive Framework Study

APPENDIX XV
WATER QUALITY, POLLUTION CONTROL AND HEALTH FACTORS
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 XV

WATER QUALITY, POLLUTION CONTROL AND HEALTH FACTORS

This report of the Lower Colorado Region Framework Study State-Federal Interagency Group was prepared at field-level and presents a framework program for the development and management of 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

This appendix prepared by the

WATER QUALITY, POLLUTION CONTROL AND HEALTH FACTORS WORKGROUP

of the

LOWER COLORADO REGION STATE-FEDERAL INTERAGENCY GROUP

for the

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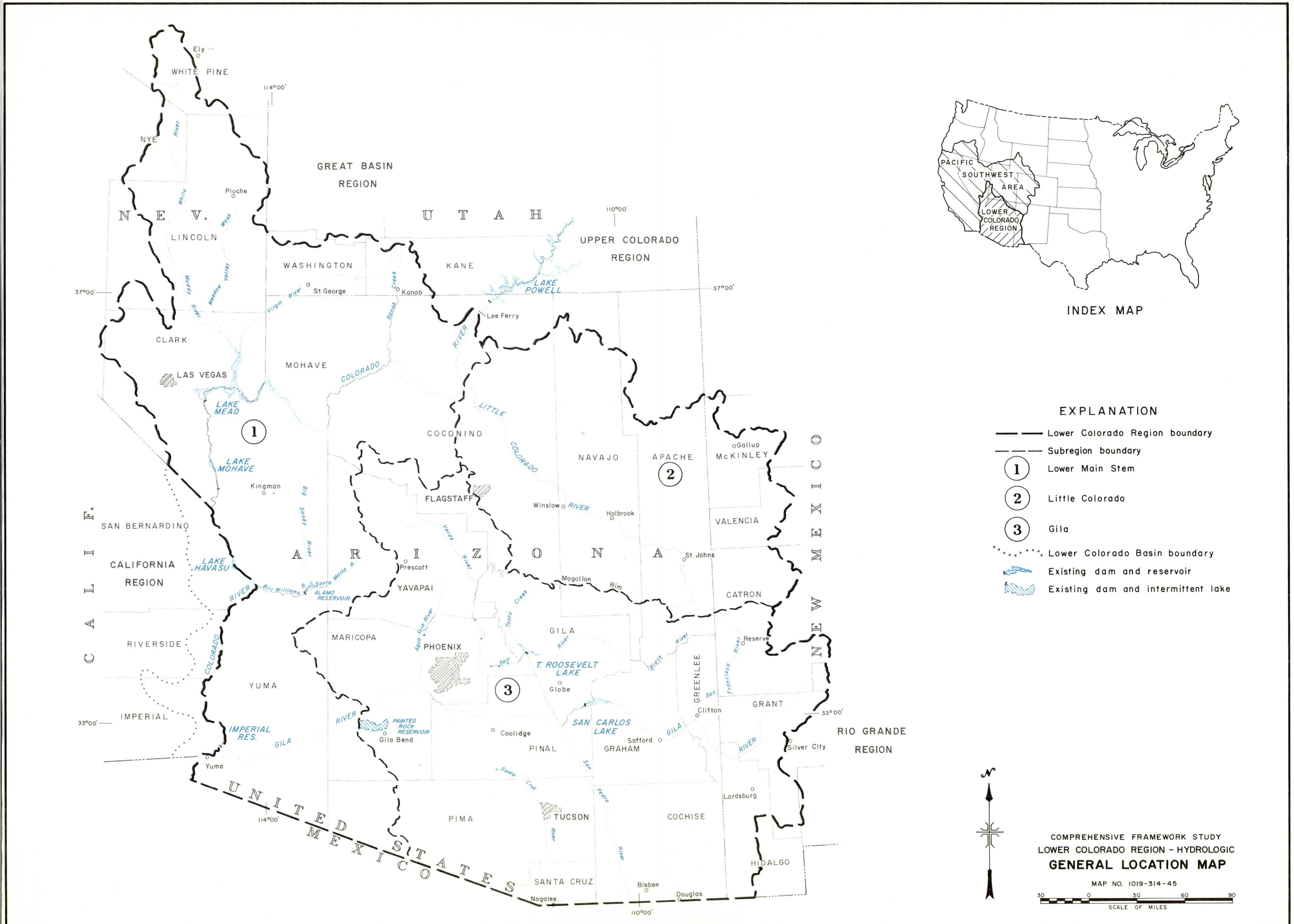
GREAT BASIN REGION
UPPER COLORADO REGION
RIO GRANDE REGION
CALIFORNIA REGION
NEV.
UTAH
ARIZONA
NEW MEXICO
CALIF.
UNITED STATES
MEXICO
WHITE PINE
NYE
LINCOLN
CLARK
WASHINGTON
KANE
MOHAVE
COCONINO
NAVAJO
APACHE
McKINLEY
VALENCIA
CATRON
YAVAPAI
MARICOPA
GILA
YUMA
PINAL
GRAHAM
GREENLEE
GRANT
PIMA
COCHISE
SANTA CRUZ
HIDALGO
SAN BERNARDINO
RIVERSIDE
IMPERIAL
LAS VEGAS
FLAGSTAFF
PHOENIX
TUCSON
LAKE MEAD
LAKE MOHAVE
LAKE HAVASU
LAKE POWELL
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SUMMARY OF FINDINGS

Salinity

High levels of dissolved mineral salts in surface and ground waters is a major water quality problem in the Region. With few exceptions, most surface and ground water supplies have mineral concentrations exceeding 500 mg/l, and many exceed 1,000 mg/l. The salinity of the supplies affects domestic, industrial and agricultural uses.

The Colorado River enters the Region at concentrations exceeding 500 mg/l, varies between 500 and 900 mg/l at most diversion points and increases to as high as 1150 mg/l for short periods of time at Imperial Dam. Nearly 8.7 million tons of dissolved solids are transported into the Region from the Upper Colorado Region annually. Increased salinity concentrations in the Colorado River from Lee Ferry, Arizona to Imperial Dam are due principally to inputs from saline springs and the concentrating effects of consumptive use, reservoir evaporation and diversions out of the Region.

In the headwaters of the Gila River, dissolved solids concentrations are generally less than 500 mg/l. In the middle reaches below points of major diversions the dissolved solids content usually range from about 500 to 1,000 mg/l. Although there are some salt springs discharging to the Gila River, most of the increase in dissolved solids result from the concentrating effects of consumptive uses.

Mineral quality is generally good in most of the headwaters of the Little Colorado River. The middle reaches of the Little Colorado vary considerably in salt content. The Little Colorado River near its mouth is very high in dissolved solids as most of the flow originates from saline springs.

Future dissolved solids concentrations in the lower Colorado River were estimated for 1980, 2000, and 2020. Dissolved solids concentrations in the Colorado River, assuming no salinity improvement program are projected to increase 40 to 60 percent by 2020. The major cause of the projected salinity increases is due to increased development which includes the additional stream depletions for municipal and industrial use, irrigation, thermal-power production, exports, reservoir evaporation, and the additional salts leached from newly irrigated lands.

State and federal representatives in both the Upper and Lower Colorado Regions agreed that the salinity improvement programs outlined in the Upper and Lower Colorado Framework Study documents would be part of a basinwide approach to salinity management. The program outlined in this appendix, therefore, is for that portion of a basinwide program that could be located in the Lower Colorado Region. There is considerable difference of opinion among the seven basin states regarding the need for a salinity improvement program. A statement setting forth the position of the states is included in the section delineating the salinity improvement program.

The salinity projections presented in Table 1 indicate the estimated effects of continued development in the absence of any augmentation programs for the basin or any salinity improvement measures and also the estimated effects of salt load reduction if the suggested basinwide salinity improvement program is undertaken.

Ground Water Management

A ground water quality management program is needed to protect the quality of the vital ground water supplies of the Region. The need is critical in the Central Arizona area to prevent further degradation in chemical quality.

Because of the intense use of water, the non-degradability of salts, and the absence of any significant outflow from the Central Arizona area, the ultimate repository for salts is the soil profile or the ground water mass. Under these conditions, deterioration of ground water quality seems inevitable. To date, water quality degradation has occurred, but only in localized areas. The timing of the overall problem on an area-wide basis has not been predicted because of the complex nature of the ground water aquifers, including the presence of gypsum and salt deposits, and the diverse and intensive pattern of water use in the area.

By the year 2000 additional augmentation through a regional importation program will begin to eliminate the ground-water overdraft in the area. The importation of Colorado River water in the Central Arizona Project area will convey additional salts to this basin. Without augmentation the increased rate of ground water overdraft may also result in degradation of ground water quality as well as having other adverse effects. Further studies are needed to define the problem and offer solutions.

Subsurface return flows from irrigated lands are expected to accumulate in some localized areas after augmentation. More than 300,000 acre-feet per year of drainage water is estimated to be available near Buckeye, Arizona by 2020. A nuclear dual-purpose desalting plant of 150 mgd capacity is suggested to treat this drainage water for reuse.

Table 1 - PRESENT AND PROJECTED CONCENTRATIONS OF DISSOLVED SOLIDS IN THE LOWER COLORADO RIVER (mg/l)

1965	1980		2000		2020	
	Without Program	With Program	Without Program	With Program	Without Program	With Program
Colorado River at Lee Ferry, Arizona						
586	650	560	760	580	820	630
Colorado River below Hoover Dam						
734	950	860	1,010	810	1,050	850
Colorado River at Parker Dam						
726	980	870	1,140	870	1,150	880
Colorado River at Imperial Dam						
839	1,260	1,100	1,290	980	1,350	1,030

Wastewater Treatment

Many improvements in municipal and industrial wastewater treatment have occurred in recent years, especially in the period 1965 to 1970. Even with this progress, there still remains a need for further improvement in wastewater treatment to control existing sources of pollution. There is also a significant need for improved operation and maintenance of existing wastewater treatment systems. In the Las Vegas, Nevada area there is a need to remove nutrients from municipal wastewaters in order to abate the pollution problems in Las Vegas Bay on Lake Mead.

As a result of the expected population growth and economic expansion, future discharges to municipal and industrial wastewater treatment works are estimated to triple--as measured by BOD--during the 1965-2020 period.

At present there is a considerable amount of reuse of water in the Region. Treated sewage is used as industrial cooling and as irrigation water. Irrigation return flows make up part of downstream supplies that are eventually reapplied to crops. Higher types of uses are projected, based on the results of pilot projects currently underway in the Region and the Pacific Southwest area. Further work will be necessary to assure the chemical, biological, and virological safety of treated wastewaters prior to implementation of those programs suggesting unrestricted use of reclaimed effluents.

The program suggested for metropolitan Las Vegas includes the construction and operation of a tertiary treatment plant to abate the pollution problem of Las Vegas Bay. The plant would vary in size from 50 mgd in 1980 to 120 mgd in 2000. It is estimated that the tertiary plant would remove nearly all of the suspended solids, color, odor, and bacteria, most of the BOD, detergent and phosphorus, and a large fraction of the nitrogen. The wastewater treatment program outlined for Las Vegas incorporates a desalting works for the renovation of secondary effluents for reuse for municipal and industrial purposes.

The suggested water quality management program for the Gila Subregion is tied to major reuse facilities for Metropolitan Phoenix and Tucson. In the program all wastes from the urbanized Phoenix area would be treated to an equivalent secondary level and the effluent applied to the land to effect additional removals by ground water recharge. A pilot project that is presently carrying out this idea is achieving encouraging results, and with the BOD, coliform, ammonia, nitrogen and phosphorus removals now achieved, the water should be acceptable for use on all types of edible crops.

The suggested wastewater treatment plan for metropolitan Tucson is similar to that described for Phoenix. The tertiary effluent would be discharged to a public aquatic park complex and to ground water recharge. This additional treatment will minimize the nitrates entering the ground water supply, a problem that currently exists north of Tucson.

Streamflow Management

Water quality improvement by means of stream flow management is limited in the Lower Colorado Region under present legal and institutional environments. The maintenance of minimum flows for water quality purposes is not recognized as a beneficial use of water in the water rights laws of any state in the Region. Availability of water in streams to maintain water quality depends exclusively on flows released to meet other downstream uses. Under existing laws, the entire flow of a stream could be periodically removed leaving the stream dry regardless of water quality criteria. Therefore, management of streams to insure minimum flows for water quality control is contingent upon purchasing existing water rights or importation.

If water quality control becomes recognized as a legitimate use, water resources management could provide for the optimum combination of quality and quantity for the available supply. In considering a streamflow management program, the effects of stream regulation on an entire river basin would have to be an integral part of any regionwide or basinwide water quality management scheme.

Land Use and Management

Opportunities to improve water quality through careful land management appear to be of the utmost significance. Land management activities are known to contribute to water quality problems; sediment and inorganic salts and minerals have a primary impact. Animal wastes, agricultural chemicals, infectious agents, turbidity, and heat are also of concern. Various aspects of the effects of land use are covered in this appendix but the net affect of land management is not fully understood. Any of the land management practices could possibly cause one or several changes in the quality of water. Some of these activities have both plus and minus effects on water quality.

Since a large percentage of the salt accretions contributing to salinity are from diffuse natural sources and irrigation return flows, potential salinity improvement benefits from improved land management practices should be fully evaluated.

Electric Power Production

A 28-fold increase in electric power plant capacity is projected by the year 2020. Nuclear-fueled thermal power generating will provide an estimated 60 percent of the electric power in the year 2020, while fossil-fueled thermal power will provide an estimated 27 percent. The remaining 13 percent will be produced by hydroelectric works.

With the tremendous thermal pollution potential of the projected power production, it is exceedingly fortunate that waste heat from power generation is amenable to treatment or control at a reasonable cost. Information presented in the Electric Power Appendix indicates that use of cooling ponds or towers is planned for future power generating works.

The selection of appropriate sites for locating power plants so as to minimize environmental damage poses a significant challenge to both the industry and government. Environmental concerns will necessitate the consideration of many more factors in the planning of power production facilities than has been the practice in the past. In addition to thermal pollution control, a number of other selection factors make siting very complicatted--aesthetic impact, available of water supply, safety, air pollution control, access to transportation and others. Installation of facilities, such as cooling towers, to control thermal pollution will affect cost factores and require more space for the plant and may make it more difficult to meet aesthetic goals. Siting is likely to become an increasingly difficult and controversial factor in the continued growth of power production. Planning for electric power plant siting should be expanded with the ultimate objective of developing a long range siting plant.

Health Factors

Data on morbidity and mortality indicate that rates of occurrence of potentially water-borne disease for the Region are higher than national rates. Better epidemiological data are needed to assess what portion of these disease occurrences are due to water-borne pathogens. The fact that infectious diseases are present emphasizes the need for continued vigilance in the areas of vector control, drinking water supplies and recreational areas.

A large portion of the Region's population presently depend on potable water supplies that do not meet the requirements of the U.S. Public Health Service Drinking Water Standards. Dissolved solids concentrations in some well systems are triple the 500 mg/l recommended limit set forth in the standards. Many surface supplies periodically exceed the standards for dissolved solids.

Several systems deliver waters that exceed recommended limits for nitrate and fluoride. Phoenix, Arizona, for example, has several wells that produce water having nitrate concentrations in excess of 100 mg/l. The Standards recommend a maximum of 45 mg/l. A few localized problems exist where systems are high in toxic materials such as arsenic and hexavalent chromium. While some of the systems are high in fluoride, the majority of the populace are served water deficient in fluoride from the standpoint of prevention of dental caries in children.

The intensity of water supply surveillance programs has tended to decrease in recent years primarily due to increased emphasis on water pollution control. Municipal water supply system surveillance is essential since many drinking water problems are due to inadequate water treatment and protection after treatment.

Water resource development agencies should prevent any additional decline in the quality of drinking waters and bring presently deficient supplies up to standards. Public water supplies should be provided from the best existing high quality waters.

Efforts should be made to upgrade the potable water systems developed for campgrounds in recreational areas. The bacteriological quality of many of these supplies is already unacceptable by the Public Health Service Drinking Water Standards.

Increased vector control activities will be needed in the future to correct present deficiencies and prevent the occurrence of new problems. Mosquito breeding locations should be eliminated during water resource project construction if possible. A need exists for increased health department surveillance and mosquito abatement district operations in much of the Region.

Increased pressures on available recreational areas, public water systems, and waste disposal facilities as a result of population expansion will require ever increasing vigilance on the part of health departments and water and wastewater works personnel. The need for increased emphasis on the part of water resources development agencies in helping to minimize the risk of spread of infectious diseases is also indicated.

The problem of disposing of solid wastes will be one of ever increasing difficulty. It is estimated that over 700 and 3,100 acres per year of storage volume will be necessary for the disposal of household, municipal, and commercial solid wastes in the years 1980 and 2020, respectively--assuming the use of sanitary landfills. Solid wastes from industry and agriculture will exceed the municipal wastes in tonnage by a large factor.

This will result in approximately 50 million additional tons per year of wastes in 1980 and over 500 million tons per year in 2020.

Radiological health problems are not of great magnitude to date. Of greatest concern will be the safety provisions in any future nuclear power plant construction and in emergency procedures to be followed in case of accidents during shipment of nuclear fuels or wastes to or from these plants.

The states of the Region either have planned or ongoing air pollution programs. Potential air pollution problems will increase in the major metropolitan areas from the influx of people and industry. The largest potential air pollution problem related to the development of water resources is in regards to thermal power generation.

LOWER COLORADO REGION COMPREHENSIVE FRAMEWORK STUDY

APPENDIX XV

WATER QUALITY, POLLUTION CONTROL AND HEALTH FACTORS

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INTRODUCTION

CHAPTER A - INTRODUCTION

PURPOSE AND SCOPE

The purpose and scope of the Water Quality, Pollution Control and Health Factors Appendix are to:

(1) Provide an overview of the pollution sources, water quality, and related environmental health conditions found in the Lower Colorado Region in the base-year 1965;
(2) Determine the future demands on water quality and health factors that may result from population growth and economic expansion in 1980, 2000, and 2020; and
(3) Compare the projected conditions with environmental-quality goals to determine the nature, timing and extent of future needs and problems, and the opportunities available to solve them.

Appendix XV presents water quality, pollution control and health factors data and programs in accordance with the following major outline:

CHAPTER A. Introduction. --This part contains a brief discussion of the Appendix and its scope and limitations.

CHAPTER B. Water Quality and Pollution Control.--This part covers the water quality and pollution control features suggested for consideration in the framework plan.

CHAPTER C. Health Factors.--This part provides an epidemiological assessment, a review of the disease vector control situation, an evaluation of drinking water supplies, and an environmental health analysis.

OBE-ERS Addendum.--This part includes an evaluation of the suitability of the water quality management programs for meeting the needs of the OBE-ERS level of development.

Framework studies are intended to be preliminary reconnaissance-type investigations. The findings of this appendix are based on the best information presently available on water quality and health factors and on immediate and potential pollution abatement needs. No detailed water-quality or environmental-health surveys were carried out specifically for the preparation of this report. The omission of any ecological problem or problem area from this document does not imply that other immediate or potential pollution abatement or environmental improvement needs do not exist.

RELATIONSHIP TO OTHER APPENDIXES

Data presented in the other appendixes were analyzed for their impact on the aquatic environment. These data, along with information contained in this report, provided the basis for development of water quality and other programs. The data and programs of this appendix were considered in formulation of the regional framework plans included in the General Program and Alternatives Appendix and the Main Report.

DESCRIPTION OF THE REGION

The Lower Colorado Region includes portions of four states, Arizona, Nevada, New Mexico, and Utah. It covers a land area of about 141,100 square miles. The 1965 population was nearly two million while present projections expect it to more than triple by the year 2020. About 45 percent of the population was concentrated in the three major cities of Phoenix and Tucson, Arizona and Las Vegas, Nevada. The primary industries are manufacturing, mining, and irrigated agriculture.

METHODOLOGY

Available sources of water quality, pollution control and health factors data were evaluated to determine base-year (1965) conditions. Data were primarily obtained from the state health departments of the four Region states, the Water Quality Office of the Environmental Protection Agency, U.S. Geological Survey, Bureau of Reclamation, U.S. Public Health Service and other federal agencies. Data sources are generally documented throughout the Appendix.

The Office of Business Economics (OBE) of the Department of Commerce and the Economic Research Service (ERS) of the Department of Agriculture provided basic projections of industrial and agricultural activity. The OBE-ERS projections, dated March 1968, served as quantitative bench marks. Modifications were made to the projections of population, irrigated agriculture, and mineral production to more nearly reflect local conditions. The Modified OBE-ERS projections were translated into such indexes as manufacturing productivity, agricultural output, etc., by the Economics Workgroup.

The projections of OBE-ERS are based on county delineation groupings called Economic Subregions that closely conform to the hydrologic subregions. Because of the insignificant differences in population and economic activity, the projections for the economic subregional boundaries were used to develop waste loadings and water qualities for the hydrologic subregions.

A computer program that calculates water quality in terms of dissolved solids concentrations at critical points in the Colorado River system in the Upper and Lower Colorado Regions was used to integrate the hydrologic characteristics, water demand data, and estimates of salt loads for 1965 and for each future target year. This program, a flow and salt-routing model developed by the Water Quality Office of the Environmental Protection Agency, was first adjusted to the base-year conditions and then used to develop estimates of the average mineral-quality in 1980, 2000, and 2020. The program was first used to compute probable concentrations of dissolved solids in streams of the Upper Colorado Region. The resulting effect at Lee Ferry, Arizona combined with the projected increased water use and development in the Lower Colorado Region were analyzed to determine the future mineral quality in the Lower Colorado River from Lee Ferry to Imperial Dam.

The computer program simulates response to input data in a series of calculations for small drainage areas. Figure 1 illustrates the method used for dividing the basin into drainage areas and establishing points of confluence of streams. Natural flow and salt loads originating within the defined drainage areas were first determined. The effects of man's activities, such as depletions of water for consumptive use or addition of salt loads by irrigation, were added to the natural effects. The program then accumulates these effects and routes them downstream to be added to successive effects.

From Figure 1 the accumulated flow and salt load below junction X would be $FR = FR_a + FR_b + FR_c$, and

$SR = SR_a + SR_b + SR_c$, respectively.

The flow equation for each drainage area would be:

$$FR_{a,b,c} = (AN \times CN) + DS - (IA \times CI) - (P \times CP) \pm DV;$$

and the salt load equation would be:

$$SR_{a,b,c} = (AN \times CN) + DS + (IA \times CI) + (P \times CP) \pm DV;$$

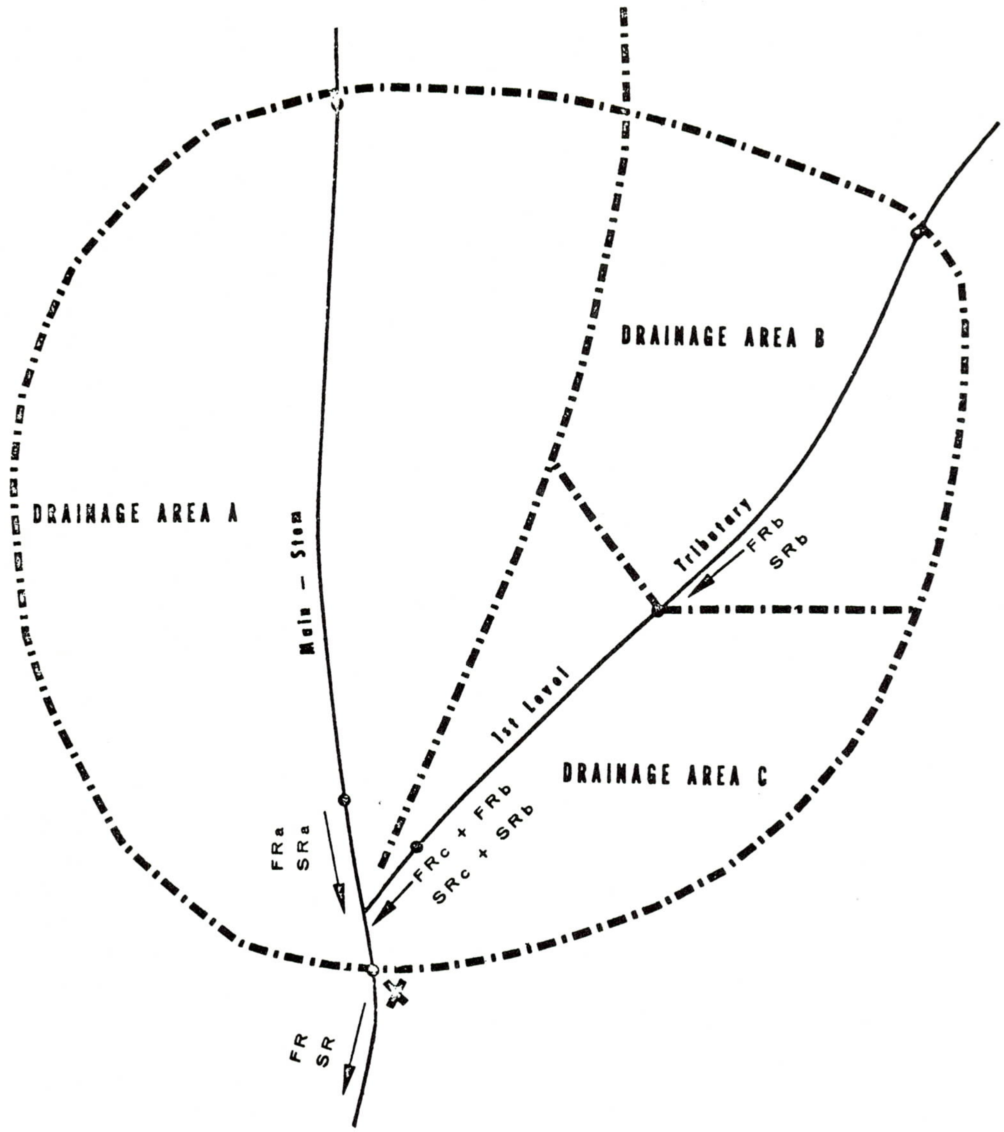


Figure 1--Typical Drainage Area Used for Flow and Salt Routing Model for the Colorado River Basin

where:

$FR_{a,b,c}$ = annual flow in acre-feet,

$SR_{a,b,c}$ = annual salt load in tons,

AN = natural drainage area in square miles,

CN = coefficient for contributions from the natural area in acre-feet/sq. mi. or T/sq. mi.,

DS = annual contribution from discrete sources in acre-feet or tons,

IA = irrigated acreage,

CI = coefficient for depletions or contributions from irrigation in acre-feet/acre or tons/acre,

P = population,

CP = coefficient for depletions or contributions by the population in acre-feet/person or tons/person, and

DV = annual diversions (imports or exports) within the drainage area in acre-feet or tons.

The base flow and salt load were based on data for the 1941-1966 period, modified to 1966 conditions of development.(33) This period was selected because it represents the longest period for which adequate salinity data are available. Adjustments for flow and salt load were made at Lee Ferry in order to correspond to the 1914-1965 period of record. Streamflow depletions, irrigated acreage, and population are from the Upper and Lower Colorado Region Type I appendixes. The salt load coefficients used for irrigation are the upper limits presented in Appendix XV except at Lee Ferry where the mean value was used. The salt coefficient for municipal and industrial sources is 50 tons per 1,000 population. Natural point sources are listed in the Upper and Lower Colorado Region Water Quality, Pollution Control and Health Factors Appendixes. The 1965 contribution from natural diffused sources is the difference between the 1965 total load and that contributed by natural point sources, irrigation, and municipal and industrial uses. The 1965 natural diffused load was assumed to remain constant throughout the study period. The drainage areas were divided, where possible, so that the stations or points selected for the routing model would coincide with the locations of USGS gaging stations.

DEFINITIONS

WATER QUALITY. A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

WATER POLLUTION. The alteration of the physical, chemical, or biological properties of water, or a discharge of any substance into water, which adversely affects any legitimate beneficial water use.

WASTEWATER. That water for which disposal is more economical than use at the time and point of its occurrence. Wastewater to one user may be a desirable supply to the same or another user at a different location. It may be wastewater because of quality, quantity, or time of its occurrence.

SEWAGE. Liquid-carried wastes of a community from domestic, service-industry, and industrial sources. (Used synonomously with wastewater herein.)

SEWERAGE SYSTEM. Sewers (pipelines and other conduits) and appurtenant facilities used for collecting or conducting wastes to an ultimate point for treatment or disposal.

WASTEWATER TREATMENT WORKS. Any mechanical or non-mechanical plant or other facility used for the purpose of treating, stabilizing or holding wastes.

PRIMARY TREATMENT. In wastewater treatment, the removal from sewage of larger solids by screening, and of more finely divided solids by sedimentation.

SECONDARY TREATMENT. The further treatment of the effluent from primary treatment by biological means. Additional physical facilities are usually employed and chemical methods are sometimes used to aid in the treatment process.

TERTIARY TREATMENT. The additional treatment of effluent, beyond that of secondary, in order to obtain a very high quality of effluent.

TOTAL DISSOLVED SOLIDS (TDS). The total solids which are present in solution in water. TDS is used as a measure of the mineral content or salinity of water.

BIOCHEMICAL OXYGEN DEMAND (BOD). The quantity of oxygen utilized primarily in the biochemical oxidation of organic matter in a specified time and at a specified temperature. (BOD data cited in this appendix are 5-day 20°C BOD.)

DISSOLVED OXYGEN. The amount of free (not chemically combined) oxygen in water. It is often used as an indicator of pollution by organic wastes.

SEDIMENT YIELD. The volume of rock, mineral material, or organic matter carried out of a watershed or to any point within the watershed.

MILLIGRAMS PER LITER (mg/l). The weight in milligrams (10^{-3} grams) of any substance contained in one liter of liquid. (A weight/volume ratio)

PARTS PER MILLION (ppm). A weight to weight ratio expressing the amount of a substance present in water.

PICOGRAM (pg). One trillionth (10^{-12}) of a gram.

WATER QUALITY AND POLLUTION CONTROL

CHAPTER B - WATER QUALITY AND POLLUTION CONTROL

PRESENT STATUS

Hydrology

The Lower Colorado Region occupies an area of 141,137 square miles. The Region includes the Colorado River drainage in the United States below Lee Ferry, Arizona, except that occurring in California. It includes several closed basins in Arizona, Nevada, and New Mexico, and some areas in southern Arizona and New Mexico that drain into Mexico. The Colorado River drainage in California (3,600 square miles) is included in the California Region.

The Region is bounded on the east by the Continental Divide in New Mexico, on the west by the State of California, on the south by Mexico, and on the north by the hydrologic boundary established at Lee Ferry, Arizona by the Colorado River Compact of 1922. These boundaries encompass most of the State of Arizona and portions of the states of Nevada, New Mexico, and Utah.

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 subregions for this study.

The Lower Colorado Region is composed of a complex of plateaus, mountains, canyons, deserts and plains, with elevations ranging from 100 feet above sea level, near yuma, Arizona, to 12,670 feet above sea level at Humphreys Peak, near Flagstaff, Arizona. Topography is found in virtually every form and degree from subdued to wild and precipitous between these elevation extremes. The geology includes a broad spectrum of sedimentary, metamorphic, and igneous rocks which each in turn or in combination produce a wide variety of soils locally and along stream courses.

Climate varies as widely as the land forms and topography. Maximum temperatures range from more than 100^{o} in the desert areas to mild 70's in the mountains. Frost-free periods range from less than 60 days in the high mountains to almost year-long in the desert valley areas.

About half the Region receives an average of less than 10 inches of precipitation per year, and a large part of the remainder receives less than 20 inches per year. In a few small areas the average annual precipitation is more than 25 inches. The southwestern part is the most arid, and near Yuma, Arizona some areas receive less than 5 inches of precipitation per year. The mountain ranges that are the headwaters of the Verde, Salt, Little Colorado, Virgin, and Gila Rivers, are the areas of highest precipitation, and a few mountain peaks receive more than 30 inches of precipitation per year.

The combination of high temperatures and low humidity in the desert areas causes high rates of evaporation and transpiration resulting in the loss of more than 95 percent of the precipitation before it reaches the streams or percolates to the ground-water reservoirs.

Surface Water

Outflow from the Upper Colorado Region constitutes the Lower Colorado Region's major surface water source. The average annual undepleted flow of the Colorado River into the Lower Colorado Region for the period of record 1906 to 1965, is 15.1 million acre-feet. Since 1963 this flow has been controlled by releases through Glen Canyon Dam, 17 miles upstream from Lee Ferry. The Colorado River Compact provides that the River at Lee Ferry will not be depleted below an aggregate of 75 million acre-feet for any period of 10 consecutive water years.

There is wide variation in annual runoff. In the desert areas, where runoff is directly dependent on rainfall, the bulk of the flow, if any, occurs during the summer--July through September. In some cases, 90 percent of a stream's annual discharge will result from one storm. Above the major surface-storage reservoirs, peak monthly runoff generally occurs during the March-June period as a result of snow accumulations in the high mountains.

The usable capacity of the principal reservoirs is about 32 million acre-feet. The high rate of evaporation produces an estimated annual lake evaporation loss of nearly 1.4 million acre-feet. Almost 90 percent of these losses occur on the major reservoirs on the lower Colorado River.

Lower Main Stem Subregion--The Lower Main Stem Subregion includes the Colorado River drainage basin in the United States from Lee Ferry to the southerly International Boundary with Mexico, with the exception of the Little Colorado River Basin, Gila River Basin above Painted Rock Dam and the California portion of the Colorado River Basin. In addition, the subregion includes Mexican drainage west of Lukeville, Arizona, and closed basins in southeastern Nevada. The total area is about 56,554 square miles, of which about 52,100 square miles contribute to the Colorado River.

From Lee Ferry the Colorado River flows through the Grand Canyon into Lake Mead which is formed by Hoover Dam 370 miles downstream from Glen Canyon Dam. Lake Mead (1965 active storage capacity 26,159,000 acre-feet) provides most of the storage and regulation of the Lower Colorado River. Proceeding downstream, Davis Dam and Lake Mohave, Parker Dam and Lake Havasu, Headgate Rock Dam, Palo Verde Diversion Dam, and Imperial Dam and Reservoir provide for re-regulation of stream flows, and storage and diversion of the river's waters for various uses. Imperial Dam, located 28 miles above the northerly international boundary, is the last major diversion point on the Colorado River for users in the United States.

The length of the Colorado River from Lee Ferry, Arizona to the southerly international boundary is about 710 miles.

The principal tributaries of the Colorado River within the Lower Main Stem Subregion are the Muddy, Virgin, and Bill Williams Rivers, Kanab, Bright Angel, Havasu, and Tapeats Creeks, and Las Vegas Wash. Outflow from the Little Colorado Subregion enters the Colorado River 60 miles below Lee Ferry. Only occasional storm flows ever reach the Colorado River from the Gila River.

Net diversions to the California Region during the calendar year 1965 totaled 5.35 million acre-feet.

Under present conditions there is essentially no outflow from the Lower Colorado Region beyond that required to meet the Mexican Treaty obligation of 1.5 million acre-feet annually.

Little Colorado Subregion--The Little Colorado Subregion encompasses the Little Colorado River drainage basin extending from the Continental Divide in New Mexico to the Lower Main Stem Subregion boundary near Flagstaff, Arizona. The Little Colorado River rises on the north slopes of the White Mountains about 20 miles above Springerville, Arizona, and flows northwestward, joining the Colorado River on the east boundary of Grand Canyon National Park. The river has a main stem length of about 356 miles and drains an area of 26,977 square miles.

Tributaries flowing from the south and west originating in the mountains along the Mogollon Rim provide most of the runoff in the Little Colorado Subregion. Winter snows prolong the flow of these streams, but during the summer most of the streams flow only after rains. Principal tributaries from the south and west are Silver, Chevelon, and Clear Creeks, and Canyon Diablo.

Runoff from the northern and eastern tributaries results primarily from rainfall during the summer months. Principal tributaries from the north and east are Carrizo, Dinnebito, and Moenkopi Washes, Corn Creek, and the Zuni and Puerco Rivers.

Lyman Reservoir (1965 active storage capacity 30,600 acre-feet) at the head of the Little Colorado River near St. Johns, Arizona is the largest reservoir in the subregion. There are many smaller reservoirs controlling headwater and tributary flows.

Present transbasin diversions to the Gila Subregion total about 15,000 acre-feet annually.

The average annual undepleted water supply of the Little Colorado Subregion is estimated at about 420,000 acre-feet. Present modified outflow from the subregion to the Lower Main Stem Subregion averages 292,000 acre-feet per year. Over one-half of the annual outflow, 160,000 acre-feet, is contributed by Blue Spring and other springs near the mouth of the Little Colorado River.

Gila Subregion--The Gila Subregion consists of the area drained by the Gila River above Painted Rock Dam except for the upper reaches of the San Pedro and Santa Cruz Rivers in Mexico. Also included are several small areas in southern Arizona and New Mexico that are either closed basins or drain to Mexico.

The drainage area of the Gila River above Painted Rock Dam is 50,900 square miles, including about 1,100 square miles in Mexico. The total area within the Gila Subregion is about 57,606 square miles, of which 49,600 square miles contributed to the Gila River. The remaining area consists of 8,000 square miles in closed basins or drainage to Mexico.

The Gila River originates near the Continental Divide, in west-central New Mexico. It is joined by the San Francisco, San Simon, and San Carlos Rivers as it flows westward through Safford Valley to Coolidge Dam. Water released from Coolidge Dam flows through remote mountain country until it reaches Ashurst-Hayden Dam near Florence, Arizona, having picked up tributary flow from the San Pedro River enroute.

The San Francisco River contributed an average 120,000 acre-feet annually to the Gila River during waters years 1961-1965. There is very little rainfall in the San Simon River Basin and the river usually flows only during storms. The average annual contribution to the Gila River from the San Simon River during water years 1961 to 1965 was 8,800 acre-feet. The San Carlos River provided an additional 21,750 acre-feet of runoff to the Gila during the same period. There were many days of no flow in the San Carlos River during this period.

Records for the San Pedro River near its junction with the Gila River indicate an annual flow of about 32,000 acre-feet during water years 1962-1965. Flow measurements of the Gila River at Kelvin, Arizona below the confluence of the San Pedro River show an average annual flow of 171,700 acre-feet during water years 1961-1965.

The only major storage provided for the Gila River above Ashurst-Hayden Dam is San Carlos Reservoir behind Coolidge Dam. The active storage capacity of San Carlos Reservoir is 984,900 acre-feet. Other upstream retention structures on the Gila River system are principally for local diversions or flood control.

All of the water reaching Ashurst-Hayden Dam is diverted for irrigation of the San Carlos Project. The Gila River below Ashurst-Hayden Dam flows through an arid desert area. Small diversion dams above the confluence of the Salt River impound the runoff from infrequent, short-duration, intense thunderstorms occurring in the area. The average flow of the Santa Cruz River at its mouth was 10,400 acre-feet during water years 1961-1965 with no flow the majority of the time. In 1965 the total measured flow in the Santa Cruz River occurred during 54 days, 60 percent of that annual flow occurred during three days.

The Salt River and its major tributary, the Verde River, produce about 70 percent of the water supply of the Gila Subregion. The Salt River System is the major surface water source for the metropolitan Phoenix area. The Salt and Verde Rivers are controlled by Granite Reef Dam above Phoenix and by other upstream dams. Essentially all of the combined flow is diverted at Granite Reef Dam. Wastewater effluents reaching the Gila River from the Phoenix area are diverted near Buckeye, Arizona for irrigation.

The average annual flow of the Salt River below Stewart Mountain Dam during water years 1961-1965 was 470,620 acre-feet. During the same period the Verde River below Bartlett Dam averaged 302,600 acre-feet annually.

Six reservoirs are located on the Salt and Verde Rivers. The largest is Theodore Roosevelt Lake with a storage capacity of about 1.4 million acre-feet. The other Salt River Reservoirs are Apache Lake, Canyon Lake and Saguaro Lake; and on the Verde River are Horseshoe and Bartlett Reservoirs. The active storage capacity of the reservoirs on the Salt and Verde Rivers is 2,072,700 acre-feet. The Agua Fria and Hassayampa Rivers are two more of the tributaries deriving most of their flow from thunderstorm activities. Only infrequently does runoff reach the mouth of these rivers.

Water accumulating in the Gila River downstream from the Salt River is diverted at Gillespie Dam located below the confluence of the Hassayampa River. The flow of the Gila River at this point is essentially return flows from the immediate upstream area. Diversions at Gillespie Dam leave a normally dry stream bed throughout the remainder of the Gila River to its mouth.

Painted Rock Reservoir, located on the Gila River 60 miles below Gillespie Dam, was constructed to provide protection to about 360,000 acres in the downstream overflow area along the Gila River from the dam site to the Colorado River, along the Colorado River from Laguna Dam to Mexico and in the Imperial Valley, California. Except for large floods or an exceptional runoff sequence, outflow from the Gila Subregion under present conditions of development would be negligible.

Ground Water

The availability and chemical quality of the ground-water resource in any area is greatly influenced by geology. These variables are further modified by the physiographic and hydrologic characteristics of the area. By grouping these characteristics, the Lower Colorado Region can be divided into three parts. These are the basin and range lowlands, the plateau uplands and the central highlands. As the discussion of ground-water characteristics will refer to these parts, a brief description of the area follows. (The relationship of these areas to the hydrologic subregions is depicted on the "General Location Map".)

The basin and range lowlands are characterized by isolated mountain blocks separated by broad alluvial-floored basins; the altitudes of the basin surfaces range from about 100 to as much as 4,500 feet above mean sea level. The altitudes of the mountain blocks are as much as 10,000 feet above mean sea level, and are usually between 1,000 and 4,000 feet above the floors of the subjacent basins. The alternating mountains and valleys were produced by large-scale faulting in which the mountain blocks were pushed upward and the basins were dropped. Subsequent to the faulting the valleys were filled with alluvial material eroded from the mountain masses. The major stages of erosion and sedimentation that formed the alluvial valleys is such that generally a coarse conglomeratic material was deposited on the basement rocks on most of the valley floors. Much of the remainder of the structural basin is occupied by an old alluvial fill which represents several ages and environments of deposition. Locally, it may be as much as 3,000 feet thick. In the upper part of the older fill, considerable thicknesses of lake-bed clays are common. The present drainages cut on the older alluvium have been filled to various depths with unconsolidated deposits of gravel, sand and silt. This younger fill forms the flood plains of present streams in many basins.

The alluvium stores large amounts of ground water and is the major aquifer in the area. The local clay beds may in some basins form confining layers and the ground water in the sand and gravel beds beneath is under artesian pressure.

The plateau uplands include a variety of land forms: canyons, buttes, mesas, and volcanic mountains. The altitude ranges from about 4,000 to 12,500 feet above mean sea level, but is mostly between 5,000 and 7,000 feet. The land forms have been carved nearly entirely from consolidated sedimentary rocks. These rocks consist mostly of sequences of alternating resistant sandstone beds and soft lime or shaley units. Differential erosion of these rocks gives the plateau country its characteristics of mesa and butte topography. The major aquifers in the area are the sandstone units which are confined by the fine grained shale layers. The sandstone units provide fairly large reservoirs for the storage of ground water.

The central highlands form a topographic high in the central part of the Region, separating the plateau uplands from the basin and range lowlands. The area consists principally of rugged, sharply pinnacled ranges and volcanic mountains, which are several thousand feet higher than the adjoining valleys of the basin and range lowlands and generally lower than the high mesa on plateau uplands. The occurrence of ground water varies areally throughout the highlands being dependent on the types of surface and subsurface rock, the structural attitude of these rocks, configuration of these mountains and valleys, and the presence of unconsolidated sediments in the mountains and alluvial floor valleys. Most of the area's rock types are impervious and contain little space for the storage of water except in localized areas of fracturing or faulting. In a few small valleys alluvial sediments provide storage for minor amounts of ground water.

Depth to water in the basin and range lowlands ranges from less than 200 feet to over 500 feet below the land surface. In a few places, such as along flowing streams, the water level is at the land surface. In other areas the depth is considerably greater than 500 feet, such as in the Hualapai and Sacramento Valleys near Kingman, Arizona. Average water levels are the deepest in the plateau uplands being generally more than 500 feet and locally in excess of 2,000 feet. Few successful wells have been drilled in an area extending from the city of Williams, Arizona north to the Grand Canyon. A test well drilled near Williams, to a depth of 2,000 feet, encountered no ground water; in this area there may well be no economically feasible ground-water supply. Within the central highlands ground water may be found at the land surface along stream channels in alluvial valleys to depths greater than 500 feet in mountainous areas. Wells flow at land surface some areas in southeastern Arizona and on parts of the Navajo Indian Reservation in northeastern Arizona.

Yields of individual wells range from less than one gallon per minute (gpm) in the hard rock of the mountains to as much as 6,000 gpm in the extensive alluvial aquifers of the basin and range lowlands. Yields of 500 gpm and up can be expected from wells tapping the extensive alluvial deposits in the basin and range lowlands with yields in the two or three thousand gpm range not uncommon. Yields of individual wells in the plateau uplands are dependent upon which of the sandstone aquifer systems the well taps. The greatest yields are obtained from zones of extensive fracturing, such as in the St. Johns area of Arizona where some irrigation wells yield from 800 to 2,000 gpm. In general, wells yield from 5 to 500 gpm throughout the area, with most wells yielding between 10 and 100 gpm. In the central highlands wells near the margins or in the shallower basins of the highlands can yield as much as 500 gpm. Yields of wells in the hard-rock areas of the mountain blocks may be less than 1 gpm; but as wells are generally located in productive aquifers, most wells are capable of producing at least 100 gpm.

Changes in water levels in the aquifers reflect changes in ground-water storage due to natural recharge and discharge or to pumping. A map depicting changes in water levels in wells in the Lower Colorado Region in 1960-1965 is contained in the Water Resources Appendix. The general trend in the Region is one of continually declining water levels. Declines have been more than 60 feet in the five-year period in the San Simon, Willcox, Lower Santa Cruz, and Phoenix basins in Arizona and in the Las Vegas basin in Nevada. Rises in water levels shown on the map have been associated with areas where drainage of applied surface water for irrigation is a problem or where natural recharge is greater than the pumpage or natural outflow. Water-level decline in the Central Arizona area has been as much as 20 feet per year in some places. Maximum decline in Central Arizona during the period 1923-1964 was about 360 feet with an average for the entire area of about 140 feet. It is predicted for this area that in the next 20 years declines may be as much as 300 feet and will average 100 feet. Throughout the Region declines can be expected to continue at current rates of decline in areas of overdraft. Changes in water levels in undeveloped areas of the Region will continue to reflect natural effects of recharge and discharge.

Water Quality Objectives and Related Considerations

Water pollution control efforts by most states and the federal government until recent years were concerned almost entirely with protection of the public health. Most of the early thrust was aimed at construction of facilities for treatment of wastes from municipalities to control the risk of water-borne diseases from humans. Water pollution and quality-control problems were not major considerations in development of land and water resources, partly because of a lack of information regarding the adverse effects of development.

State-Federal Water Quality Standards

The principal stimulus for expansion of pollution control programs was provided by the Water Quality Act of 1965 which amended the Federal Water Pollution Control Act (61) and required the states to establish water quality standards for interstate streams within their boundaries by June 30, 1967. Section 10 of the Water Quality Act delineates this requirement as follows:

> "Standards of quality established pursuant to this subsection shall be such as to protect the public health or welfare, enhance the quality of water and serve the purpose of this Act. In establishing such standards the Secretary (now the responsibility of the Administrator of the Environmental Protection Agency) the Hearing Board, or the appropriate state authority shall taken into consideration their use and value for public water supplies, propagation of fish and wildlife, recreational purposes, and agricultural, industrial, and other legitimate uses."

Along with water quality standards, the states were asked to furnish a plan for putting the standards into effect and for enforcing them. Regional states set a minimum of secondary treatment or its equivalent for municipal and industrial wastewaters when they adopted their water quality standards. The standards and their implementation plans are, in themselves, plans for controlling pollution. Upon acceptance by the Secretary of the Interior the water quality standards became joint state-federal standards.

Tables 2, 3, 4, and 5 provide an inventory of uses of interstate streams of the Region and the water-quality standards set by the states. 1/ Intrastate streams have not been classified according to use; however, basic water-quality criteria apply to the streams. Water-quality standards have not been established for ground water.

1/ References: 52, 53, 54, 56

Table 2 - INVENTORY OF USES AND WATER-QUALITY REQUIREMENTS1/

State of Arizona

Lower Colorado Region

Zones	Miles	Present(P) & Future(F) Water Uses		Fecal Coliform count/ml	pH	Temp. °F	Turbidity Jackson Units	Radio-activity	DO mg/1	Biocides
The Colorado River main stem from Utah line to southerly international boundary with Mexico and all Arizona tributaries.	730	Irrigation	PF	--	6.5-8.6	--	--	< PHS Standards for drinking water	--	Below harmful levels
		Public Water Supply	PF	Mean < 1000/100; 10% of samples: < 2000/100	6.5-8.6	$< 93^\circ$	Warm waters < 50 Cold waters < 10		--	
		Ind. Water Supply	PF		6.5-8.6	$< 93^\circ$			--	
		F&W habitat2/	PF		6.5-8.6	4/			> 6	
		Recreation(primary contact)	PF	Mean < 200/100; 10% of samples: < 400/100	6.5-8.6	$< 93^\circ$			--	
The Gila River system, defined to comprise the Gila and four major tributaries, the San Francisco, San Simon, San Pedro and Santa Cruz Rivers. (All other tributaries are considered intrastate.)	480*	Irrigation	PF	--	6.5-8.6	--	--	< PHS Standards for drinking water	--	Below harmful levels
		Public Water Supply	PF	Mean < 1000/100; 10% of samples < 2000/100	6.5-8.6	$< 93^\circ$	Warm waters < 50 Cold waters < 10		--	
		Ind. Water Supply	PF		6.5-8.6	$< 93^\circ$			--	
		F&W habitat3/	PF		6.5-8.6	4/			> 6	
		Recreation(primary contact)	PF	Mean< 200/100; 10% of samples < 400/100	6.5-8.6	$< 93^\circ$			--	

* The Gila main stem from New Mexico line to mouth.

1/ Taken from Arizona Water Quality Standards documents.

2/ Cold water fishery: Utah line to head of Lake Mead; Hoover Dam to Topock.
Warm water fishery: Remainder.

3/ Cold water fishery: Headwaters of San Francisco River.
Warm water fishery: Remainder.

4/ Cold water fishery: Winter $< 55^\circ$; Summer $< 70^\circ$
Warm water fishery: $< 93^\circ$

Table 3 - INVENTORY OF USES AND WATER-QUALITY REQUIREMENTS 1/

State of Nevada

Lower Colorado Region

Zones	Miles	Present(P) & Future(F) Water Uses	Fecal Coliform	pH	Temp. °F	DO mg/1	BOD mg/1	NO_3 mg/1	PO_4 mg/1
Colorado River	140	Public Water Supply PF Ind. Water Supply PF Recreation(contact) PF Fish & Wildlife PF Irrigation PF Aesthetics PF Waste Assimilation PF Power PF	Below Hoover Dam and in Lake Mead 2/	3/ Annual median: 7.5-8.2 Single value: 7.0-8.5	3/ Summer single value: < 65° Winter single value: < 58°	3/ June through September Average: > 6.0 Single value: > 5.0	3/ Single Value: < 2	3/ Annual average: < 4 Single value: < 7	Pending
				4/ Annual median: 7.5-8.0 Single value: 6.5-8.5	4/ Summer single value: < 68° Winter single value: < 58°	4/ June through September Average: > 6.0 Single value: > 5.0	4/ Single value: < 3	4/ Tentative Annual Average: < 5 Single value: < 7	Pending
Virgin River	30	Fish & Wildlife P Irrigation P Aesthetics P Waste Assimilation P	--	5/ Annual median: 7.3-8.0 single value: 6.5-8.5	5/ Summer single value: < 86° Winter single value: < 58°	5/ June through September Average: > 6.5 Single value: > 6	5/ Single value: < 5	5/ Single value: < 1	5/ Annual average: < .04 Single value: < .08

1/ Taken from Nevada Water Quality Standards documents.

2/ MF Coliform/100 ml (Average of the last five samples)
Maximum value of 1000 if MF Fecal Streptococci are less than 100.
Maximum value of 5000 if MF Fecal Streptococci are less than 20.
To apply to all swimming areas of the Colorado River within Nevada.

3/ Below Hoover Dam and in Lake Mead.

4/ Below Davis Dam.

5/ At Mesquite.

Table 4 - INVENTORY OF USES AND WATER-QUALITY REQUIREMENTS[1/]

State of New Mexico

Lower Colorado Region

Zones	Miles	Present(P) & Future(F) Water Uses	Fecal Coliform count/ml	pH	Temp. °F	Radio-activity	DO mg/l	TDS	Toxic Substances
Gila River above Gila Hot Springs (East, Middle, & West Forks)	95	Fishery (trout) PF Irrigation PF Domestic PF Industrial PF	Mean of 5 samples < 2000/100	6.6-8.6	< 70°, increases limited to < 2°	<u>All Zones</u>: < PHS Drinking Water Standards 1962 or < 1/30 of 168-hour values specified in National Bureau of Standards Handbook 69	> 50% of saturation or > 6.0 (the higher value)	<u>All Zones</u>: Limit degree of degradation within means available through current technology	<u>All Zones</u>: < 10% of median 48-hour tolerance limit for particular form of aquatic life
San Francisco River above Reserve, New Mexico	--	Same as above	Same as above	6.6-8.6	Same as above		Same as above		
Gila River from Gila Hot Springs downstream to New Mexico state line	80	Fishery(warm water) PF Irrigation PF Domestic PF Industrial PF	Mean of 5 samples < 2000/100	6.6-8.6	< 93°; increases limited to < 5°		> 5.0[2/]		
San Francisco River from Reserve to New Mexico state line	50	Same as above	Same as above	6.6-8.6	Same as above		Same as above		

1/ Taken from New Mexico Water Quality Standards documents.

2/ 50% of the saturation concentration for 8 hours per 24-hour periods for the particular stream conditions or 5.0 mg/l whichever is the higher oxygen concentration.

Table 5 - INVENTORY OF USES AND WATER-QUALITY REQUIREMENTS 1/

State of Utah

Lower Colorado Region

Zones	Miles	Present(P) & Future (F) Water Uses	Classification	Chemical & Radiological	Radio-active Substances	pH	Total Coliforms count/ml	BOD mg/l	DO mg/l	Temp.
Virgin River	-	Livestock WS PF Irrigation WS PF F&W Propagation PF Recreation (swimming only in selected approved areas) PF Public Water Supply F Ind. Water Supply F	CW	< PHS Drinking Water Standards 1962	< 1/30 of 168-hour values of National Bureau of Standards Handbook 69	6.5-8.5 and no change > 0.5 unit from other than natural causes	Monthly Arithmetic Mean < 5000/100 with exceptions	Monthly Arithmetic Mean < 5.0 with exceptions	Shall not be < 5.0	Protected as C water; also against in-crease of > 4°F; not to exceed 80°F.
Kanab Creek	-	Same uses as above	C	Same as above	Same as above	Same as above	Same as above	Same as above	Same as above	Protected against controllable heat dis-charges

1/ Taken from Utah Water Quality Standards documents.

Future revision of standards will be necessary as uses change and other conditions necessitate revision.

At the present time, about 94 percent of the total withdrawal from ground-water and surface-water sources is used for irrigated agriculture and 6 percent for municipal, industrial and other uses. Sixty-two percent of all withdrawals in the Region come from ground water.

Principal Pollution Control Agencies

The Arizona Board of Health was created in its present form by the Arizona Legislature in 1954 to provide authority for controlling wastes from domestic and industrial sources. The Arizona Water Quality Control Act was passed into law by the Arizona State Legislature on March 16, 1967. The Act broadened the authority of the Arizona State Department of Health with respect to water pollution control and established a 13-member Water Quality Control Council to adopt a program of water pollution control and supervise the administration and enforcement of water quality standards. Authority for controlling pollution from irrigation is placed in the Water Quality Control Council. Authority for controlling pollution from municipalities and industries remains with the State Board of Health.

The Nevada State Health Department is designated as the official water pollution control agency for Nevada and is charged with the protection of the quality of water resources, including establishment of regulations and standards for wastewater discharges and with taking corrective actions to abate pollution.

The 1967 New Mexico Legislature established a State Water Quality Control Commission composed of the heads of six agencies. The Water Quality Control Commission is the official water pollution control body for New Mexico and has the prime responsibility for maintaining water quality in the state. The Act grants the Oil Conservation Commission exclusive authority to prevent water pollution resulting from oil and gas operations. The Water Quality Control Commission is responsible for the establishment and enforcement of water quality standards and regulations under the Federal Water Pollution Control Act. The Commission does not maintain a staff and surveillance and administrative duties are assigned to constituent agencies.

The 1953 Utah Legislature enacted a revised public health code giving the State Department of Health certain specific power relating "....to the quality of the effluent from sewerage systems, sewage treatment plants and trade wastes discharged upon the land, or into the surface or ground waters". Classification of streams and establishment of water quality criteria and other actions taken pursuant to the Federal Water

Pollution Control Act were performed jointly by the Utah Water Pollution Control Board and the Utah State Board of Health. The Utah Legislature changed the name of the Water Pollution Control Board to the Committee on Water Pollution in 1967. The Utah Oil and Gas Conservation Commission has authority over pollution of ground and surface waters caused by oil-field operations.

The Water Quality Office of the Environmental Protection Agency carries out the provisions of several public laws relating to water pollution control. Further discussion of the role of the Environmental Protection Agency in water quality activities and a delineation of legislative authority are contained in the Legal and Institutional Environments Appendix. Other federal agencies are actively involved in water pollution control efforts in accordance with specific authorizations contained in various acts.

State-Federal Enforcement Actions

The Federal Water Pollution Control Act of 1948 provides for state-federal enforcement conferences as a means of abating water pollution. At the request of the states of Arizona, California, Colorado, Nevada, New Mexico and Utah, the Surgeon General of the Public Health Service called a conference on the interstate pollution of the Colorado River and its tributaries. Six conference sessions have been held as follows:

First session:	January 13, 1960 (52)
Second session:	May 11, 1961 (53)
Third session:	May 9-10, 1962 (54)
Fourth session:	May 27-28, 1963 (55)
Fifth session:	May 26, 1964 (56)
Sixth session:	July 26, 1967 (57)

Private, state, and federal interests have been represented at all of the conferences.

All participating interests recognized initially that the Colorado River does present a water quality management problem. The Public Health Service, in cooperation with the states, agreed to undertake a study to define the types of interstate pollution problems which might exist. The study was to include determination of the nature and extent of pollution problems and their effects on water users, and recommendations for remedial measures. This study was continued by the Federal Water Quality Administration and represents in land area the largest water pollution control study ever undertaken.

Although all types of pollution problems were to be considered in the study, the most critical and pressing problems were to be given priority and remedial measures developed.

The most pressing pollution problem in the Colorado River Basin at the time of the first session, in the opinion of the conferees, was water pollution caused by the discharge of radioactive wastes. Remedial action was undertaken through the cooperation of private, state, and federal interests. At the fourth session, such significant progress was indicated in the control of radioactive discharges that the conferees then gave studied priority to salinity problems.

Prevention and Abatement of Pollution from Federal Facilities

Executive Order 11507 on pollution control from federal facilities was issued on February 4, 1970. This Order requires that all projects or installations owned or leased by the federal government be designed, operated and maintained in conformance with present and future water quality standards. The Executive Order provides for strict compliance and establishes a deadline by which existing facilities must comply with environmental standards. This comprehensive plan for pollution abatement includes control, not only of water pollution, but also of air pollution by federal facilities.

In a subsequent Executive Order issued on March 7, 1970 implementing the landmark National Environmental Policy Act of 1969, the President set forth additional procedures to assure that federal programs will meet national environmental goals. He directed that attention be given to federal policies, including administration of loans, grants, contracts, and licenses, to minimize their pollution impact.

Enactment by the Congress of the Water Quality Improvement Act of 1970 adds further force to this effort by requiring that applicants for federal permits, for activities such as construction of nuclear facilities or reservoirs, meet applicable water quality standards.

Pollution Sources

Municipal Wastes

The population of the Lower Colorado Region totaled 1,877,000 people in 1965. Seventy-five percent of the population lived in the Gila Subregion, 18 percent in the Lower Main Stem Subregion, and seven percent in the Little Colorado Subregion. An estimated 80 percent of the population of the Region lived in urban areas of 2,500 inhabitants or more.

Over 70 percent of the Region's population is concentrated in the metropolitan areas of Phoenix, Tucson, and Las Vegas. Maricopa County, Arizona, with its 1965 population of 835,000 centered in the metropolitan Phoenix area contained 45 percent of the Region's population. Pima County, Arizona with Tucson as the population center contained 314,000 people, and Clark County, Nevada had a population of 211,000 with most of it concentrated in the urbanized Las Vegas area.

Major cities in the Lower Main Stem Subregion besides metropolitan Las Vegas are Yuma, Arizona, 1965 population 25,000, and St. George, Utah, population 6,000. In the Little Colorado Subregion the largest communities are Flagstaff, Arizona, population 20,000, and Gallup, New Mexico and Winslow, Arizona, each with populations of about 10,000 in 1965. In addition to the large populations concentrated in Maricopa and Pima Counties, populations between 10,000 and 15,000 are found elsewhere in the Gila Subregion in the Arizona cities of Nogales, Casa Grande, Prescott, Bisbee and Douglas.

Included in the municipal-waste category are domestic wastes released to private disposal facilities from food service and lodging establishments, schools, mobile-home courts, hospitals, and similar installations.

Municipal wastewaters possess many highly varied and variable chemical, physical, and biological characteristics. Biochemical oxygen demand (BOD), total dissolved solids (TDS), and phosphorus (P), have been selected as the parameters to represent the pollutional potential of municipal wastes. BOD measures the oxygen-depleting capacity of organic wastes and is the parameter most commonly used to analyze municipal wastes. Total dissolved solids indicate the quantity of mineral salts present and was selected because of the salinity problem in Regional waters. Phosphorus was chosen as the basis for nutrient determinations because in some cases it is the most critical element causing eutrophication problems. Other parameters are important because of public health and water quality significance but were not selected because it was believed that these three parameters were broadly representative of present and potential problems. Parameters such as coliform bacteria were not evaluated because they can easily be reduced to safe levels at the wastewater treatment plant.

Dissolved mineral constituents in municipal discharges are important because they add to the salt burden of receiving waters. The added salts are derived from many sources; a significant portion of the increase results from the use of sodium chloride (ordinary table salt).

A marked increase in the phosphorus content of domestic wastewaters has occurred in recent years due to the increased use of phosphate-based detergents. Detergents may account for as much as one-half of the phosphorus present in municipal effluents. Although the problems associated with excess fertility of lakes and streams are attributed to nutrients from many sources, municipal wastes often represent the largest nutrient source.

Total waste production of domestic origin in the Lower Colorado Region during 1965 is estimated to have included 59,000 tons of BOD, 137,000 tons of TDS, and 2,800 tons of phosphorus.

Table 6 - ESTIMATED ANNUAL DOMESTIC WASTE PRODUCTION - 1965
(tons/year)

	BOD	TDS	P
Lower Main Stem Subregion	11,000	25,000	500
Little Colorado Subregion	4,000	9,000	200
Gila Subregion	44,000	103,000	2,100
Lower Colorado Region	59,000	137,000	2,800

Economic sectors that describe commercial, service, and governmental activities are considered as service industries. It is estimated that service-industry wastes contained 4,000 tons of BOD, 8,600 tons of TDS, and 170 tons of P.

Table 7 - ESTIMATED ANNUAL SERVICE-INDUSTRY WASTE PRODUCTION
1965
(tons/year)

	BOD	TDS	P
Lower Main Stem Subregion	800	1,800	30
Little Colorado Subregion	200	400	10
Gila Subregion	3,000	6,400	130
Lower Colorado Region	4,000	8,600	170

Domestic wastes are divided into three classes: (1) urban; (2) rural non-farm; and (3) rural farm. It is assumed that all urban and one-half of rural non-farm domestic wastes are discharged to municipal collection facilities. All rural farm and the remaining half of rural non-farm wastes of domestic origin are defined as rural domestic and described later in the Rural-Domestic Wastes section.

The distribution of urban and rural populations was estimated from demographic data showing estimates of the 1965 urban-rural division and rural farm and non-farm statistics from the 1960 census.[14][24]

Table 8 - ESTIMATED DISTRIBUTION OF POPULATION - 1965

	Urban	Rural Non-Farm	Rural Farm
Lower Main Stem Subregion	79%	18%	3%
Little Colorado Subregion	36	52	12
Gila Subregion	84	14	2
Lower Colorado Region	80%	17%	3%

Domestic wastes conveyed to municipal sewers approximated 89 percent of the total domestic waste production. This varied from 91 and 88 percent in the Gila and Lower Main Stem Subregions respectively to 62 per cent in the Little Colorado Subregion. The estimated populations served by public sewerage systems were about 304,000 in the Lower Main Stem Subregion, 78,000 in the Little Colorado Subregion, and 1,400,000 in the Gila Subregion. Municipal wastes of domestic origin are listed by subregion in the following table.

Table 9 - ESTIMATED MUNICIPAL WASTES OF DOMESTIC ORIGIN - 1965
(tons/year)

	BOD	TDS	P
Lower Main Stem Subregion	9,500	22,000	400
Little Colorado Subregion	2,500	6,200	100
Gila Subregion	40,000	94,000	1,900
Lower Colorado Region	52,000	122,200	2,400

Service-industry effluents entering municipal collection systems are included in municipal wastes. It is assumed that service-industry waste loads enter the collection system in the same proportion as the domestic waste load. Service-industry waste products which are not conveyed to public sewers make up about one percent of the Region's municipal production. These wastes are assumed discharged to individual disposal facilities, primarily septic tanks.

Table 10 - ESTIMATED MUNICIPAL WASTES OF SERVICE-INDUSTRY ORIGIN
1965
(tons/year)

	BOD	TDS	P
Lower Main Stem Subregion	700	1,600	25
Little Colorado Subregion	100	200	5
Gila Subregion	2,500	6,000	120
Lower Colorado Region	3,300	7,800	150

Several factors affect the characteristics of wastes received at municipal treatment works. Included are age, temperature, dilution from infiltration or storm water, and the amount and nature of industrial wastes discharged to the system. These, in turn, affect the performance of the waste treatment facilities. Under normal conditions, primary treatment removes about 35 percent of the BOD and 50 percent of the suspended solids. Secondary treatment effects levels of removal approximating 85 percent for BOD and suspended solids with upper limits approaching 95 percent if properly designed and operated.

The degree of bacteria removal varies considerably according to the type of treatment provided. Regardless of the treatment methods applied, large numbers of bacteria remain in the effluent, restricting its suitability for use. Satisfactory control of pathogenic organisms is contingent upon adequate removal of solids with subsequent disinfection of the plant effluent, usually by chlorination. Properly digested sludge may be used for fertilizer or may be disposed of in a number of other ways without imposing health hazards.

Conventional means of wastewater treatment do not adequately remove nutrients. Primary treatment removes limited quantities of nitrogen, but virtually no phosphorus. The amount of nitrogen and phosphorus removed by trickling filters and activated sludge systems varies considerably. For this analysis it was assumed that an average of 15 percent of the phosphorus was removed by conventional secondary treatment.

Normal methods of treatment have practically no effect on total dissolved solids. It is estimated that the overall removal from all processes is only about 5 percent which is attributed to the limited precipitation of some minerals.

The effectiveness of any waste treatment installation depends on many factors in addition to the type of processes employed, or the presence of various physical components and systems. The volume and characteristics of the wastewater will have a significant impact on performance. Other factors affecting treatment include planning, design, construction, operation and maintenance of the treatment system. More efficient waste treatment could probably be obtained from a majority of the existing treatment works if better operation and maintenance were provided.

One-hundred thirty-two sources of municipal waste disposal were identified in the Lower Colorado Region for 1965. 1/ Treatment provided during 1965 is summarized in Table 11.

1/ References: 10, 11, 31, 44, 50, 52, 53, 54, 56, 57

Table 11 - MUNICIPAL WASTE TREATMENT - 1965
(Number of Systems)

	Lower Main Stem Subregion	Little Colorado Subregion	Gila Subregion	Lower Colorado Region
Secondary	18	6	34	58
Lagoon	5	12	38	55
Primary	1	1	1	3
Septic Tank	2	2	10	14
No Treatment	2	0	0	2
Total	28	21	83	132

The largest source of municipal wastes in the Lower Main Stem Subregion is the metropolitan Las Vegas area. In the urbanized area of Las Vegas Valley municipal waste treatment plants are operated by the cities of Las Vegas and Henderson, Clark County Sanitation District and Nellis Air Force Base. The City of North Las Vegas is served by the Las Vegas facility.

The second largest municipal waste source in the Lower Main Stem Subregion, Yuma, Arizona (1965 population 25,000) discharged untreated sewage into the Colorado River in 1965. The City of Yuma commenced operation of a wastewater treatment plant during July 1970.

The population of the Little Colorado Subregion is predominately rural. The largest communities--Flagstaff and Winslow, Arizona, and Gallup, New Mexico,--operate wastewater treatment plants.

Sixty percent of the municipal wastes produced in the Lower Colorado Region are generated in the metropolitan Phoenix area. This area includes the cities of Phoenix, Tempe, Mesa, Scottsdale and Glendale plus 17 smaller communities. It has been estimated that about 75 percent of the 800,000 people residing in the valley metropolitan area are served by a community sewer system.(12)(60) About 80 percent of the collected wastewater was treated at the two City of Phoenix sewage treatment plants. The remaining collected wastes were processed in nine smaller treatment facilities. Numerous individual septic tank systems served the unsewered population.

The City of Tucson wastewater treatment plant treats the wastes from an estimated 95 percent of the 250,000 metropolitan Tucson population. Domestic wastes were also discharged to eleven small municipal sewage disposal systems located in the metropolitan area.

Information on each installation was analyzed and treatment efficiencies estimated. Based on the individual evaluations, it was determined that 13,000 tons of BOD, 123,000 tons of TDS, and 2,200 tons of phosphorus remained in effluents released from municipalities. Hence, the overall effectiveness of reducing waste loads through the various processes employed in the Region was estimated as 77 percent for BOD, 5 percent for TDS, and 14 percent for phosphorus.

A summary of the estimated waste removal efficiencies for municipal waste treatment works is presented in the following table.

Table 12 - ESTIMATED MUNICIPAL WASTE TREATMENT EFFICIENCIES
1965
(Percent Removal)

	BOD	TDS	P
Lower Main Stem Subregion	73	5	11
Little Colorado Subregion	68	5	22
Gila Subregion	78	5	14
Lower Colorado Region	77	5	14

Estimates of the municipal wastes produced and wastes remaining after treatment are shown in the table below.

Table 13 - ESTIMATED MUNICIPAL WASTE SUMMARY - 1965
(tons/year)

	Before Treatment			After Treatment		
	BOD	TDS	P	BOD	TDS	P
Lower Main Stem Subregion	10,200	23,600	425	2,700	22,000	380
Little Colorado Subregion	2,600	6,400	105	800	6,000	80
Gila Subregion	42,500	100,000	2,020	9,500	95,000	1,740
Lower Colorado Region	55,300	130,000	2,550	13,000	123,000	2,200

Effluents from the treatment works are either discharged to the nearest watercourse or diverted for irrigation or industrial use. Although the majority of the wastewaters are discharged to waterways, only part of the return flows ever reach flowing streams. Many of the receiving channels are dry throughout much of the year and effluents seep into stream beds within a short distance below outfalls. Additional wastewater and waste products may reach ground-water aquifers from many waste stabilization ponds due to percolation through the bottom of the ponds.

Direct reuse of municipal effluents for irrigation is practiced extensively in the Lower Main Stem and Gila Subregions. Sewage effluents are used in the Las Vegas area for cooling water at two thermal power-generating plants. A survey of the wastewater treatment facilities serving metropolitan Las Vegas showed that in 1967 twenty percent of the effluent from these installations was used for irrigation, eight percent was diverted for use as cooling water, and 72 percent was discharged to Las Vegas Wash. [5] At some mining communities in the Gila Subregion municipal waste treatment plant effluents are used as process waters in mineral-leaching operations. The disposition of municipal effluents is estimated in the following table.

Table 14 - ESTIMATED DISPOSITION OF EFFLUENTS - 1965

	Watercourse	Irrigation	Industrial
Lower Main Stem Subregion	75%	20%	5%
Little Colorado Subregion	95	5	0
Gila Subregion	65	30	5
Lower Colorado Region	70%	25%	5%

Downstream recovery of municipal effluents is common in the Region. Return flows from the Phoenix area are added to the normally dry Salt River, then quickly recaptured at Buckeye and diverted for irrigation.

Projects aimed at demonstrating the feasibility of using tertiary treatment for the reclamation of municipal effluents for uses requiring high quality water are being conducted in the Phoenix and Tucson areas. The Flushing Meadows Project at Phoenix is a cooperative endeavor between the Salt River Project and U. S. Water Conservation Laboratory. The objective of the Flushing Meadows Study is to determine the feasibility of renovating secondary sewage effluent from the metropolitan Phoenix area by means of ground water recharge in the dry Salt River bed. One of the potential users for the renovated water is irrigated agriculture. Experimental results are encouraging and with the BOD, coliform, ammonia, nitrogen and phosphorus removals now achieved, the water should be acceptable for use on all types of edible crops.

The Tucson Wastewater Reclamation Project is similar to the Santee Project located in the California Region. The objectives of the Tucson Project are to demonstrate the chemical, biological and virological safety and aesthetic acceptability of renovated wastewater by constructing, maintaining and monitoring a multi-stage tertiary treatment facility to serve a public aquatic park complex and ground water recharge system.

Rural-Domestic Wastes

Characteristics of rural-domestic wastes differ only slightly from domestic wastes produced in urban areas. The major difference being that waste constituents generally are more concentrated in rural wastewaters resulting from lower rates of household water use. These factors have little effect on the quantity of wastes produced as measured by the selected parameters presented in the Municipal Wastes section. Consequently, the same load factors were used to estimate both urban and rural-domestic wastes.

In the Lower Colorado Region in 1965, rural-domestic wastes are estimated to have contained 6,800 tons of BOD; 15,600 tons of TDS; and 330 tons of phosphorus.

Table 15 - ESTIMATED RURAL-DOMESTIC WASTE PRODUCTION - 1965
(tons/year)

	BOD	TDS	P
Lower Main Stem Subregion	1,300	3,000	70
Little Colorado Subregion	1,500	3,400	80
Gila Subregion	4,000	9,200	180
Lower Colorado Region	6,800	15,600	330

Two types of waste disposal facilities are usually found in rural areas: septic tank-soil absorption systems and pit provies, with the former most common in the Region. In some rural areas undesirable cesspools continue to be a part of the sewage facilities.

Efficiencies of treatment provided by septic tanks are comparable to those afforded by primary treatment works. Hence, large quantities of dissolved and suspended solids remain in the tank effluent, which is also characterized by a high BOD. Bacteria densities, although decreased in the digestive process, remain at hazardous levels. Also present in the effluent are the soluble products of sludge decomposition including ammonia, nitrites, and nitrates. By use of the leaching field, further reduction in the pollutional nature of the wastewater is accomplished through soil filtration and biological action by soil bacteria.

No estimates have been made of the amount of waste products entering ground water. Under certain conditions, physical, chemical and bacteriological pollution of groundwater supplies may result from subsurface wastewater discharge. Within the unsaturated zone, movement of pollutants is normally restricted to the downward direction; little movement occurs in the horizontal direction as the material is transported through the soil by water originating either from seepage or rainfall. Once the pollutants reach the water table, direction of movement is determined by the direction of ground-water flow.

Industrial Wastes

Industrial wastes include spent process waters, cooling waters, wash waters and other wastewaters associated with industrial activities. Included in this section are manufacturing and mining wastes.

Although pollutional characteristics of industrial wastes vary widely, generalized characteristics can be noted for various forms of industrial activity. For example, food processing wastes normally are high in organic solids; cyanide and heavy metals may be found in metal plating wastes; and mining and milling processes produce highly mineralized waters that may be toxic. The major pollutants from cooling water discharges are heat, dissolved solids, and corrosion control additives.

An assessment of the pollutional nature of an industrial waste should consider dissolved and suspended inorganic and organic solids, pesticides and other toxic materials, oil and grease, acidity or alkalinity, floating materials, temperature, color, taste and odor-producing substances, bacteria, and radioactivity. Due to the wide variety of pollutants found in industrial effluents, it is difficult to determine possible effects from waste discharges because of the antagonistic and synergistic aspects of the waste constituents.

Efforts were made to analyze industrial wastes in the same manner as municipal wastes in order to provide a comparison of the sources. Biochemical oxygen demand and dissolved solids were estimated for manufacturing sectors. BOD contributions from mining and milling are considered minimal and were not estimated. High concentrations of dissolved solids are found in mining wastewaters; yet, data were unavailable to provide meaningful estimates of total waste production and discharge. Phosphorus in industrial wastes could not be quantified because of a lack of data.

The BOD test has limited reliability as a measure of the strength of non-human wastes. However, other analytical methods for determining the oxygen demand of the oxidizable material in industrial wastes do not provide a ready comparison with BOD.

There is no general index of the toxicity of chemical pollution; therefore, each industrial waste must be analyzed on an individual basis for specific chemical pollutants. Although the presence of many chemical constituents will be reflected in the results for dissolved solids, the tolerances of chemicals vary considerably and many chemicals are highly toxic in extremely minute concentrations.

Manufacturing--The largest producers of gross wastes in the Lower Colorado Region are the Food and Kindred Products, Chemicals and Allied Products, and Primary Metals sectors. The Food and Kindred Products sector consists mainly of soft drink plants, bakeries, dairies, meat packers, and canned and frozen food processors. The chemical industries are principally engaged in the production of agricultural fertilizers, industrial organic and inorganic compounds, paints, detergents and sanitary chemicals, insecticides and explosives. Many of the establishments in the Primary Metals sector process copper concentrates.

Most of the manufacturing activity is located in the metropolitan areas of Phoenix, Tucson and Las Vegas in the Gila and Lower Main Stem Subregions. Activity outside these areas is generally in either the materials-oriented industries or in food processing to serve local markets. In the Little Colorado Subregion, lumber and wood products account for most of the manufacturing output.

Proper waste control becomes increasingly important due to this pattern of industrial location as manufacturing operations are concentrated in large population centers or at points of raw-material availability. In populated areas disposal of industrial effluents is compounded by the problems of disposing municipal wastewaters.

Some generalized observations can be made regarding waste production and disposal in the Region. Over one-half of the manufacturing firms in Arizona were built since 1950.[18] The economic output of the Region increased 300 percent between 1955 and 1965 according to data in the Economic Base and Projections Appendix. From these two factors it can be assumed that most of the manufacturing is done in relatively modern facilities employing modern, efficient methods of production to minimize material losses. Additionally, concern for conservation of water indicates that these same modern installations would be equipped for optimum utilization of the water resource.

Manufacturing activity within the Region generated 31,000 tons of BOD and 87,000 tons of TDS in 1965. By comparison, a national study showed that total BOD production from manufacturing operations in the United States amounted to 11 million tons in 1964.[47] Subregional tabulations of gross waste production are presented in the following table.

Table 16 - ESTIMATED WASTE PRODUCTION FROM MANUFACTURING ACTIVITIES - 1965
(tons/year)

Manufacturing Sector	BOD	TDS
Lower Main Stem Subregion		
Food and Kindred Products	2,200	3,800
Chemicals and Allied Products	2,000	2,300
All Other Manufacturing	500	1,900
	4,700	8,000
Little Colorado Subregion		
Food and Kindred Products	600	1,000
All Other Manufacturing	100	300
	700	1,300
Gila Subregion		
Food and Kindred Products	17,000	30,000
Chemicals and Allied Products	1,700	4,500
Primary Metals	1,500	7,500
All Other Manufacturing	5,300	36,000
	25,500	78,000
Lower Colorado Region	30,900	87,300

National estimates indicate that production of wastes from manufacturing, as measured by BOD, were about triple those from municipal sources.(47) A similar Regional analysis shows the manufacturing component as about two-thirds of municipal production. This may reflect the differences in the type and magnitude of manufacturing, or it may reflect errors in the estimates. Several factors may have affected the estimates especially because municipal loads are based on fairly firm data for the Region and industrial loads are based on national data adjusted by Regional data.

The methodology developed for computation of waste production from manufacturing in the Region involved utilization of both local and national data with the differences being reconciled to best conform to Regional conditions. Waste loads were estimated on the basis of a waste contribution/employment relationship. Waste production was computed by manufacturing sectors, in part because of the availability of employment statistics by sector, and in part due to the general similarity of waste characterisitics within a sector.

The only study of industrial waste production in any part of the Region was an inventory of waste sources with loads expressed in terms of BOD, for industries in Utah.(55)

These data were supplemented by national estimates of waste production by manufacturing sectors, including BOD loads and limited TDS data.(47) Empirical BOD/TDS ratios were developed from several sources to further estimate TDS loads.

Unit waste factors were derived from the waste loads and employment data provided in the Utah survey and from national employment statistics.(22) Waste production, in turn, was calculated using estimates of employment in the Region.(18-20)

The deficiencies of assessing industrial pollution by the methods used must be recognized. The load factors were established on a Regional basis for use in subregional tabulations, and it is not meant to imply that the loads would apply to any specific facility. Furthermore, it must be realized that industrial wastes are measured in very broad terms. This approach is considered consistent with the objective of a Type I Framework Study, however, and should serve to provide a comparison of the relative significance of waste sources.

The discharge of water-borne wastes from manufacturing establishments, according to BOD loads, is estimated to conform to the following distribution.

Table 17 - ESTIMATED DISTRIBUTION OF WASTE LOADS 1/ DISCHARGED FROM MANUFACTURING ESTABLISHMENTS - 1965

	Land Disposal 2/	Public Sewers	Water-course
Lower Main Stem Subregion	10%	55%	35%
Little Colorado Subregion	5	70	25
Gila Subregion	5	75	20
Lower Colorado Region	5%	70%	25%

1/ As measured by BOD.
2/ Includes irrigation diversions, seepage-evaporation disposal, and subsurface drainage from septic tanks.

The lack of a comprehensive inventory of industrial waste-water handling practices precludes a complete review of the adequacy of waste-control measures due to limited knowledge of the nature of the waste products, the type and efficiency of treatment processes, and the portion of waste flow treated. In general the references cited for municipal waste treatment provided the basic information on industrial waste treatment.

A majority of industries discharge their wastes to public sewers, often after pretreatment to remove objectionable materials that could have detrimental effects on the operation of municipal treatment works. Some industries provide treatment for their liquid waste products and then release them to nearby waters or divert them for other in-plant or off-site uses.

Methods used by manufacturing establishments for treatment include: (1) biological processes, similar to those used for municipal waste treatment; (2) chemical methods to neutralize acid or alkaline wastewaters, to remove color and to precipitate dissolved material; (3) physical means for removing suspended and floating solids. A combination of methods will usually best suit the needs of an industry.

There are no known cases in the Region of disposal of manufacturing wastes by deep-well injection.

It is estimated that wastes from manufacturing in the Region received treatment that removed 70 percent of the BOD and 5 percent of the TDS prior to discharge to waterways. The amount of dissolved matter entering ground water supplies was not estimated but it is possible that much of the soluble inorganic material was carried into underlying aquifers due to seepage through pond bottoms.

As a result of the concentration of manufacturing activity in the Metropolitan Phoenix and Tucson areas, the Gila Subregion accounted for 85% of the gross BOD and 90% of the gross TDS produced in the Region. Water pollution controls were tighter in the Subregion due to both a higher incidence of water re-use and a greater use of public sewers.

Estimates of waste removal are based on water-use patterns, locations of manufacturing activities, types of products manufactured, prevalence of control methods in industries, and estimates of treatment afforded industrial wastes by municipal facilities.

Table 18 - ESTIMATED TREATMENT OF MANUFACTURING WASTES - 1965
(Percent BOD Removal)

Lower Main Stem Subregion	55
Little Colorado Subregion	70
Gila Subregion	75
Lower Colorado Region	70

A summary of gross waste production and net waste remaining in manufacturing effluents is presented below.

Table 19 - ESTIMATED MANUFACTURING WASTE SUMMARY - 1965
(tons/year)

	Gross Production		Net Discharge	
	BOD	TDS	BOD	TDS
Lower Main Stem Subregion	4,700	8,000	2,100	7,600
Little Colorado Subregion	700	1,300	200	1,200
Gila Subregion	25,500	78,000	6,400	74,000
Lower Colorado Region	30,900	87,300	8,700	82,800

Potential sources of mercury, a pollutant of recent concern, are believed to be largely limited in the Region to paint manufacturers. Phenyl mercury compounds are used as a mildew preventive in latex paints. Field investigations are currently underway to determine the presence of mercury in surface and ground waters.

Mining--The principal pollutants associated with the mining sectors are acid, heavy metals, dissolved solids, and radioactive material derived from liquid and solid wastes. Process waters containing various chemical constituents from the addition of reagents and extraction of minerals represent a serious pollutional hazard in the event of accidental or intentional release. The erosion of disturbed mining areas further contributes to pollution of the streams of the Region.

Arizona leads the nation in the production of copper, producing over one-half of the national total. Copper production is centered in the Gila Subregion with limited activity in the Lower Main Stem Subregion. Lead, zinc and sand and gravel are other major mineral commodities.

Data were unavailable to provide an overall assessment of the gross wastes generated, the effects of abatement and control measures, and the resulting waste discharges from mining and milling operations.

Arizona ranked fourth in the nation in 1965 in the amount of crude and waste materials handled at surface mines.[34]

Due to the low-grade ore mined, the majority of the material is waste. Lands disturbed by surface and strip mining in Arizona as of January 1, 1965, amounted to 32,400 acres or 0.5 percent of the state's area.[34] Reclamation of 4,700 acres, or about 15 percent, of this area has been identified as a need[34]. Much of this barren land lays in arid climatic zones; however, sediment containing heavy metals and other minerals is eroded from barren land surfaces and waste piles and transported to waterways by the infrequent storms.

Process waters used for concentrating ores are the major source of wastewaters associated with mining. Sulfide ores of copper, lead and zinc are concentrated by flotation. Copper is extracted from low-grade oxidized ores by leaching. Leaching produces a copper sulfate solution which is passed over a bed of shredded iron to precipitate the copper. The remaining iron sulfate solution represents the most potent liquid-waste product from copper mining.

Recirculation of process waters is practiced extensively in the Region.[35][36][37] Certain process applications allow only once-through use of the water. These spent process waters are usually considered as waste and disposed of by evaporation in retention ponds. Limited quantities of wastewaters are chemically treated and released to waterways.

The generally accepted practice in the Region which is to pond and hold process water for reuse or disposal alleviates many of the potential pollution problems. Lined or sealed ponds are used in some areas to minimize the risk of ground water contamination.

Recent studies by the State of Arizona indicate pollution from metal mining activities in the Gila River Basin.[9] Adverse effects have been noted on Mineral Creek and the Gila River below Mineral Creek due to high concentrations of copper in the water. Mining operations along Chase Creek near Morenci, Arizona were also cited as possibly degrading the waters of Chase Creek and the Gila River.

Proper disposal of wastes from uranium processing is essential because significiant radioactivity is found in both the solid and liquid wastes. During operation of the now-closed Tuba City mill, all liquid wastes were held in holding ponds for disposal by evaporation and seepage. No known surface discharges occurred. Water quality investigations of surface and ground water in the vicinity of the mill indicated that levels of radioactivity were within acceptable limits.

The Tuba City uranium mill was closed in 1967, but may reopen at a later date to meet the projected demands of the electric-power industry.

Sand and gravel production can be either a wet or dry process. Dry processes remove sand and gravel deposits by washing and screening to separate sand and gravel from clay, silt and other unwanted material. A study of water use in Arizona in 1960 indicated that 350 gallons of water were used to wash a ton of sand and gravel.[35] These washwaters were reported to be usually discharged to the land surface for recharge of the aquifer.

Agriculture

Irrigation Return Flow--Approximately 1,200,000 net acres of land were irrigated in the Lower Colorado Region in 1965. Of this total, about 895,000 acres are located in the Gila Subregion. Most of the remaining acreage is located in the Lower Main Stem Subregion in the vicinity of Parker and Yuma, Arizona.

Salinity--The major impact of irrigation on water quality in the Region is from the salt-concentrating effect due to the consumptive loss of water. Irrigation is a consumptive use of water inasmuch as an average of 2/3 of the farm delivery is lost by evaporation from water and land surfaces, and by the transpiration of plants. Little, if any, of the dissolved salts carried in irrigation water is used by the plants. The dissolved salts in the applied water are thus concentrated in the remaining 1/3 of the water. The dissolved solids concentrations in drainage water can be further increased by the leaching of salts from the soil profile. Water leaching irrigated lands can pick up relatively high salt loads; the amounts generally decrease with time after initial applications to new lands. Ample water must be applied to carry away excess salts from the soil to avoid significant crop-yield reductions. Each reuse of irrigation water results in more salts concentrated in less water.

Data quantifying the amount of salt leached from irrigated lands are presently limited. Studies are underway to evaluate salt returns from irrigation in some areas. Analyses of return flows from the Colorado River Indian Reservation, one of the largest concentrations of irrigated land in the Lower Main Stem Subregion, indicated that irrigation water leaching soils increased the mineral burden of the Lower Colorado River by an additional 17,600 tons of salt in Water Year 1964.[48] Averaged over the 31,900 acres of land irrigated, the per acre yield was about 0.5 tons annually. The major portion of land probably added little or no salt load while the area developed from 1960-1969 probably added much more than 0.5 tons per acre per year. The pickup of salt from new lands is significant when it is considered that the reservation has water rights for an additional 67,500 acres and development of new lands is continuing.

Irrigation return flows are not routinely monitored for quality. Results of TDS sampling in the Lower Main Stem Subregion are presented in Table 20. Data describing the quality of return flows in other areas are not available, although data presented in the Present Water Quality section show a six-fold increase in the dissolved solids concentration in the 113-mile reach of the Gila River from the Arizona-New Mexico border to Bylas, Arizona. The data are from an Arizona State Department of Health Study which cited the salt concentrating effect of irrigation as one of the probable causes for the increase.[9]

Table 20 - DISSOLVED SOLIDS CONCENTRATIONS IN PRINCIPAL IRRIGATION DRAINS

Location	TDS (mg/l) Min.	Mean	Max.
Colorado River Indian Reservation (32,000 acres)			
Main Drain near Parker, Arizona	979	1,185 1/	1,400
BuRec Drain near Parker, Arizona	778	807 1/	833
Lower Main Drain near Parker, Arizona	1,090	1,940 1/	2,750
Yuma Area (150,000 acres)			
Gila River 2/ (includes North & South Gila Valley drainage) near Yuma, Arizona	1,150	2,307 1/	4,440
Wellton-Mohawk By-Pass Channel near Yuma, Arizona	3,350	4,700 3/	5,460
Main Drain 4/ near San Luis, Arizona	1,500	1,650 5/	1,790

1/ Average of 52 samples taken weekly during Water Year 1964.
2/ The Gila River flow is reconstituted entirely by agricultural drainage.
3/ Average of 72 samples taken weekly between 7/67 and 12/68.
4/ The Main Drain does not join the Colorado River in the United States.
5/ Average of 52 samples taken weekly between 12/67 and 12/68.

A major cause of the high salt content of the Colorado River below Yuma is the discharge of saline drainage waters from the Wellton-Mohawk Irrigation and Drainage District. The Wellton-Mohawk Drain carries ground water pumped from drainage wells that are operated to control the elevation of the water table.(17) Ground water underlying the district is highly saline. Previous irrigation with ground water caused the quality to deteriorate from continued evapotranspiration and recirculation.

The wells are selectively pumped to control salinity of water delivered to Mexico. Occasional flows from the Gila River present problems to the pumpage operations. The salt load discharged to the Colorado River from the Wellton-Mohawk Main Outlet drain averages about 1.3 million tons per year.(39) The estimated average annual canal flow is about 217,000 acre-feet. The dissolved solids concentration averages about 4,400 mg/l. Salinity concentrations of the pumped ground water have been decreasing since commencement of pumping.

In 1961 Mexico protested to the United States on the marked increase in the salinity of the Colorado River water being delivered to Mexico. The increase in salinity was principally incident to discharges into the Colorado River of water pumped from the saline aquifer underlying the Wellton-Mohawk Irrigation District. In 1965 the Presidents of the United States and Mexico announced approval of a 5-year interim agreement covering construction and operation of a bypass channel designed to route the more saline drain water past Morelos Dam which diverts water for use in irrigation in the Mexicali Valley in Mexico.

Pesticides--Pesticides used on agricultural lands in the Lower Colorado Region may reach streams in irrigation return flows or, in some cases, may be carried into the ground water by the downward movement of applied irrigation waters. Data are not available to estimate the quantity of pesticides used Regionwide; however, a study of pesticide use in Arizona revealed that 1,750 tons of pesticides and herbicides were used on Arizona farmlands during 1965.(1) About 94 percent of all irrigated lands in the Region are located within the State of Arizona.

Table 21 - USE OF PESTICIDES IN ARIZONA

		Tons Applied in 1965		
Subregion	Counties	Chlorinated Hydrocarbons	Organic Phosphates	Other & Herbicides
Lower Main Stem	Yuma	211	47	-
Gila	Maricopa, Pinal, Pima, Cochise, & Graham	806	180	-
	Other 8 Counties	26	6	-
Total-State of Arizona		1,043	233	475

The chlorinated-hydrocarbons group of pesticides are quite persistent and are of primary concern because of their long-range impact on the environment. Chlorinated hydrocarbons receiving the largest use were DDT and Toxaphene. Dylox, Malathion and Parathion were the organic phosphates most commonly used.

The main period of application of insecticides, herbicides, defoliants, and other chemicals begins in May, rises to a peak in August, and returns to a low level in November.

Much of the irrigated development in the Lower Main Stem Subregion is in Yuma County where the climate is favorable for year-round cropping. The crops which require the heaviest applications of pesticides are cotton, lettuce, citrus, and alfalfa. Cotton and lettuce receive repeated chemical applications within each season as they are subject to a variety of pests. More than 30,000 acres of cotton and 15,000 acres of lettuce are found in Yuma County.

In 1965 there were 315,000 acres of cotton, 138,000 acres of alfalfa, 35,000 acres of lettuce, and 16,000 acres of citrus crops grown in the Gila Subregion, all of which required repeated applications of pesticides. According to the pesticide-use survey, over 800 tons of chlorinated hydrocarbons were applied to the subregion's crops that year.

A 1969 study of pesticide use in Arizona analyzed trends in the amounts and types of pesticides used during the four-year period 1965-1968.[51] The study found that pest abundance and subsequent use of pesticides were primarily a function of the weather. Annual sales of chlorinated hydrocarbons nearly tripled from 1965 to 1967. The use of DDT to combat a widespread infestation of pink bollworms in cotton-growing areas during 1967 was the major factor in this increase. Additionally, the increased resistance of many pests to DDT brought about more intensive applications. Annual sales of organic phosphates increased 290 percent from 1965 to 1967.

Legislation restricting the use of DDT in Arizona resulted in an 80 percent decline in DDT sales from 1967 to 1968. Parathion, an organic phosphate, has replaced DDT to a large extent as an insecticide in Arizona agricultural operations. There was also a marked increase in 1968 in the sales of Toxaphene and Strobane, both chlorinated hydrocarbons. Total pesticide sales increased slightly from 1967 to 1968.

Top soil in alfalfa fields in the Salt River Valley in the central portion of the Gila Subregion is reported to contain about three pounds of DDT and DDE per acre.[2]

A discussion of the presence of pesticides in waters of the Region is presented in the Present Water Quality section.

Fertilizers--Nitrogen and phosphate fertilizers find widespread use on farms in the Region. Agricultural data for 1964 indicate that 41,500 tons of fertilizers were applied on 180,000 acres in the Lower Main Stem Subregion; 235 tons applied on 2,700 acres in the Little Colorado Subregion; and 167,300 tons applied on 895,000 acres in the Gila Subregion.[23]

Fertilizers are a source of the nitrogen and phosphorus found in surface waters. Nitrates in ground water have been traced, in part, to the use of fertilizers, but little phosphorus enters ground water due to the affinity of soil particles to adsorb phosphates. Fertilizers are carried into surface streams by irrigation return flows and runoff from infrequent thunder storms. The erosion of soil containing adsorbed phosphates is the major route whereby agricultural phosphates reach waterways. Significant quantities of phosphates may also be transported by the return flows of well-drained, irrigated soils.

No investigations have been conducted in the Little Colorado or Gila Subregions to determine the addition of nutrients to streams resulting from the use of fertilizers on agricultural lands. Furthermore, no water-quality data for nutrients are available for these subregions. In 1966, a biological survey of the Colorado River found that significant quantities of phosphorus were contributed by irrigated agriculture.[40] At the time of the survey, soluble phosphorus entered the Colorado River from irrigated lands on the Colorado River Indian Reservation at the rate of 1.2 pounds per day, an annual load of 9 pounds per square mile, assuming constant return rates.

Wide variations in the quantity of nutrients reaching streams from fertilized areas can be expected as many factors affect both the amount of fertilizers applied and the amount moved from agricultural lands. It is interesting to note that this same 1966 survey found that soluble phosphorus contributed to the Colorado River from an irrigated area west of the River in the California Region amounted to 31 pounds per day or 86 pounds per square mile annually.

Measurements of phosphorus in the inlet and return canals of the Colorado River Indian Reservation indicated an increase in the concentration of total phosphorus from 10 mg/l to 41 mg/l and an increase in the concentration of soluble phosphorus from less than 5 mg/l to 27 mg/l, resulting in an increased phytoplankton population from the inlet to the outlet of the irrigation system. The extent of the increase was not enough to interfere with uses of the water.

Animal Wastes--Most of the livestock in the Region are scattered over the range where potential contamination of water supplies or the possibility of causing health problems are less than from animals kept in confinement. Only those animals concentrated in feed lots or on poultry ranches were considered as potential waste sources for this study.

Table 22 - NUMBER OF LIVESTOCK FEEDLOTS AND POULTRY RANCHES

	Cattle Feed Lots		
	Size-Number of Animals		
	500-2,999	3,000-9,999	10,000-50,000
Lower Main Stem Subregion	16	5	1
Little Colorado Subregion	0	0	0
Gila Subregion	69	23	11
Lower Colorado Region	85	28	12

Poultry Ranches

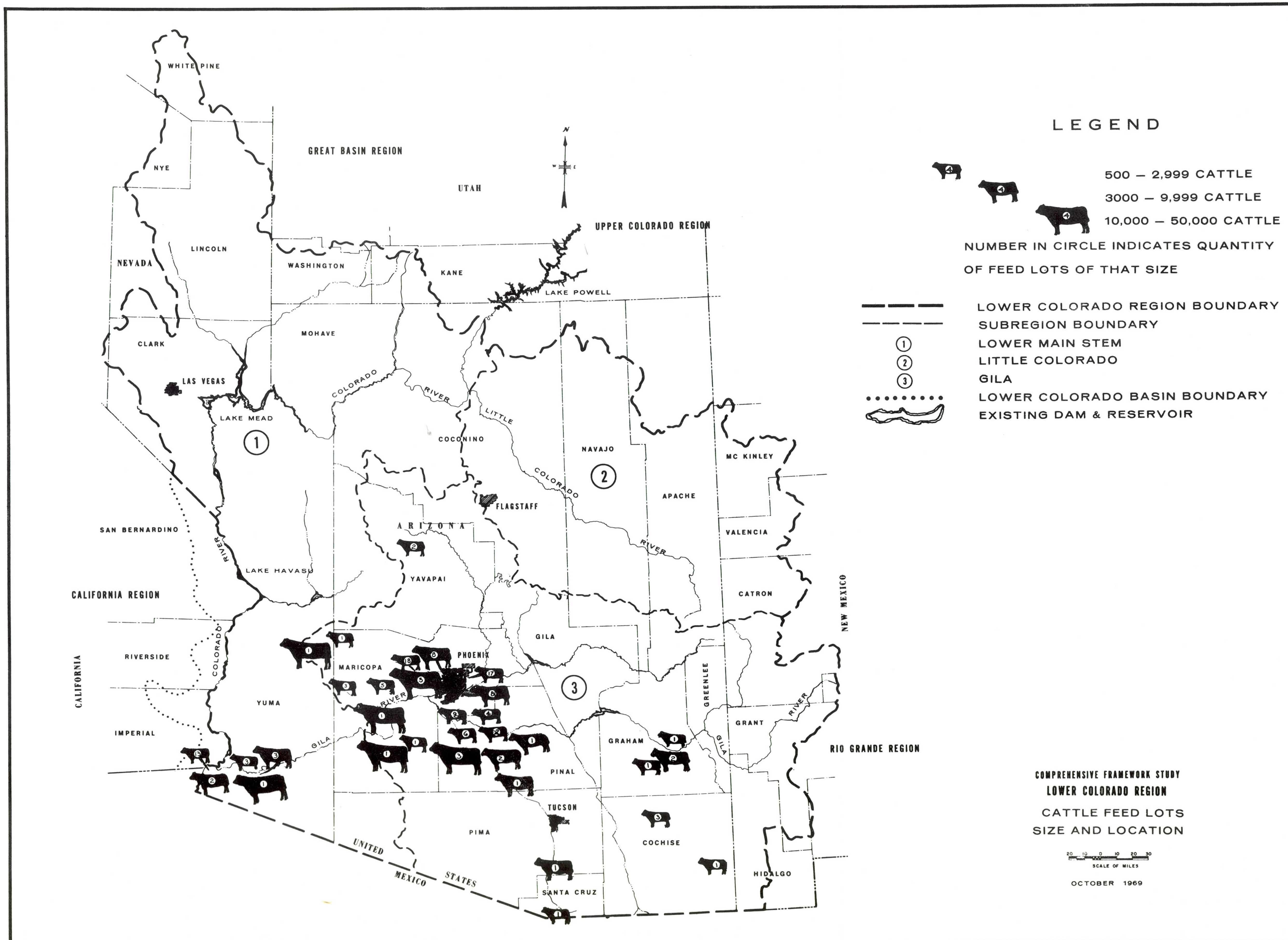
	Size-Number of Animals		
	300-4,999	5,000-29,999	30,000-100,000
Lower Main Stem Subregion	2	3	0
Little Colorado Subregion	4	1	0
Gila Subregion	45	20	13
Lower Colorao Region	51	24	13

Hog Feed Lots

	Size-Number of Animals		
	200-499	500-999	1,000-10,000
Lower Main Stem Subregion	1	0	0
Little Colorado Subregion	1	1	0
Gila Subregion	13	9	13
Lower Colorado Region	15	10	13

Locations of the feedlots and poultry ranches are shown on the maps on the following pages. The tables and figures accompanying this section are for the year 1967 instead of the base year 1965. While a noticeable change has taken place in the number of small operators, the total number of stock or poultry has not changed appreciably.

For the purpose of this study it was estimated that the Region contained 683,500 cattle, 46,200 hogs, and 1,112,000 pountry. Animal wastes from these sources are estimated to have produced 149,000 tons of biochemical oxygen demand, 48,500 tons of nitrogen, and 15,000 tons of phosphorus during 1965.

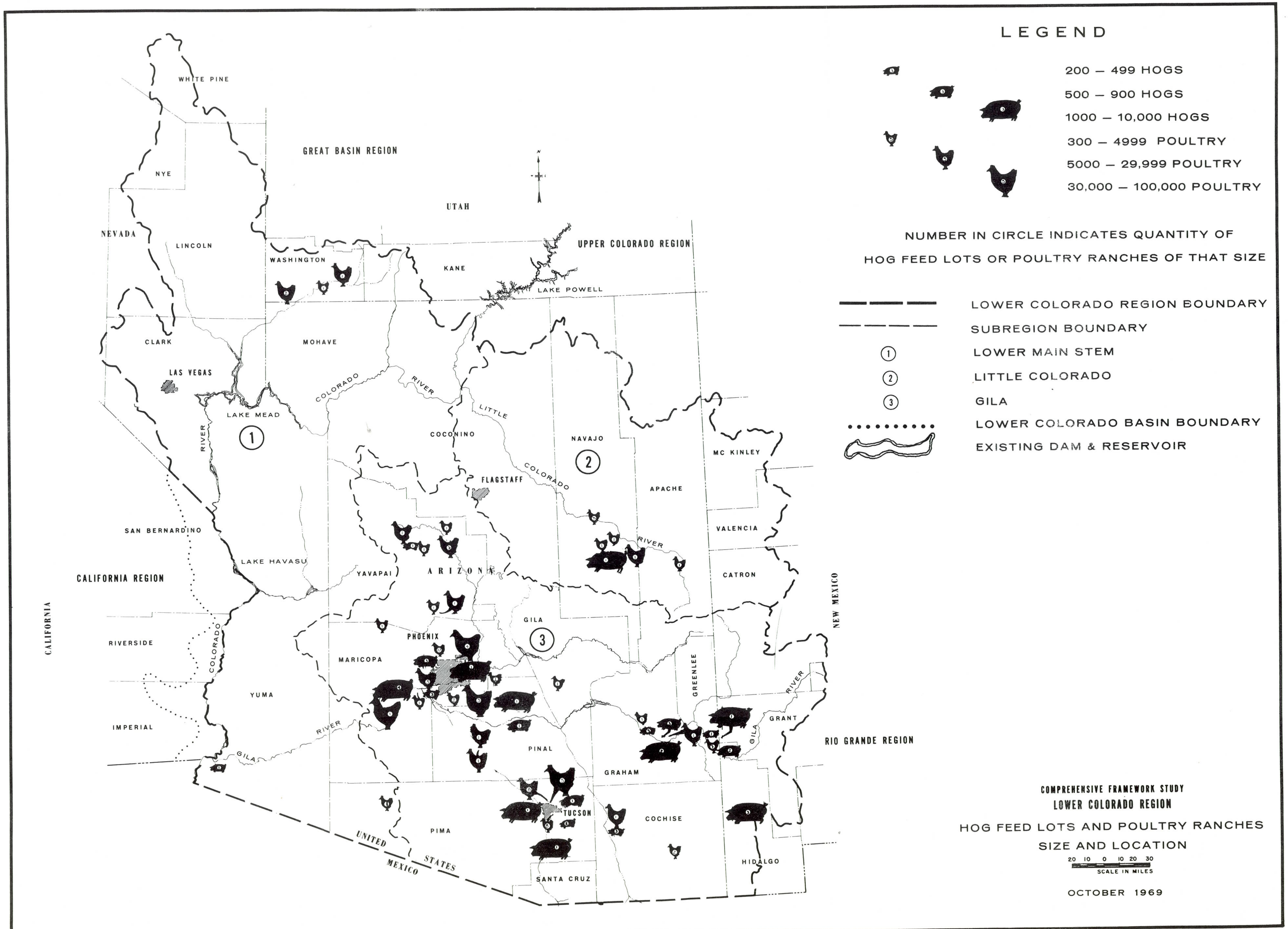


COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION

CATTLE FEED LOTS
SIZE AND LOCATION

OCTOBER 1969

GPO 856-793



COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION

HOG FEED LOTS AND POULTRY RANCHES
SIZE AND LOCATION

20 10 0 10 20 30
SCALE IN MILES

OCTOBER 1969

GPO 856-793

Table 23 - ESTIMATED WASTE PRODUCTION FROM LIVESTOCK AND POULTRY IN CONFINEMENT
(tons/year)

	BOD	N	P
Lower Main Stem Subregion	18,200	6,200	1,900
Little Colorado Subregion	400	50	30
Gila Subregion	130,500	42,300	13,000
Lower Colorado Region	149,100	48,550	14,930

Factors used for estimating animal waste production are shown in the following table.(58)

Table 24 - MAJOR FERTILIZING ELEMENTS OF ANIMAL EXCREMENT PER 1,000 POUND OF LIVE ANIMAL WEIGHT
(pounds/year)

Element	Cattle	Hogs	Poultry
Biochemical Oxygen Demand 1/	398	328	3,650
Nitrogen	138	185	333
Phosphorus	41	110	253

1/ Based on estimated weight: cattle - 1,000 lbs; hogs - 300 lbs; and poultry - 5 lbs.

Nationally, the major cause of pollution from feed lots is stream runoff from the lot. Within the Region, this problem is minimal because outside surface water has been prevented from entering the feed lot either by diverting drainage away or by location of the facility in a favorable topographic position. Also, runoff is low because of the low annual precipitation.

Few, if any, of these operations are on the banks of perennial streams where animal waste can normally contribute directly to stream pollution. In most cases these facilities are located adjacent to intermittent streams or in some location on the valley floor where it would be unlikely that animal wastes could reach a stream of any kind under normal climatic conditions. It is quite likely, however, that many feedlots are in flood plain areas and are thus a hazard during periods of flooding.

That portion of the water which moves into the ground water may affect the quality of the ground water. Filtration through soil will remove most of the oxygen demanding wastes and most of the soluble phosphates and thus minimize the amounts that might enter the ground water. Some of the nitrogen in the form of soluble nitrates may leach down through the soil and enter the ground water. The overall effect will depend on the nature and permeability of the subsurface materials and depth to water table. The water which moves below the root zone would bring into solution some of the salts which occur naturally in the material it contacts in its downward movement. The water with the accumulated salts could affect the ground water supplies if it reaches the water table. The time required for water from the surface to reach deep ground water supplies is not known. Therefore, it would seem that possibility of ground water contamination from agricultural sources is related more to depth of water and the nature of the material through which the recharge water must move than to the original quality of the water.

Feedlots and poultry ranches are generally located adjacent to urban areas where they may constitute a health problem. Some disease organisms are transmitted through animal wastes, either by direct or indirect human contact. Although less is known regarding transmissions of viral diseases directly to humans, animal wastes provide a harbor for reproduction of insect sectors of viral diseases. Animal wastes also provide nutrients and a medium for fungal disease pathogens to multiply, as well as increasing the prevalence of disease in animal hosts. Esthetically speaking, the odors produced in feed lots can be very offensive to residents of the area. Dust from feed lots can aggravate respiratory conditions.

Recreation

Water-Related Recreation Areas--The concentration of recreational activities in small areas during short periods of time makes wastes from recreation particularly significant. Disposal of wastes from recreation areas become increasingly important because of the rapid growth in recreation use and development. The problem is further compounded because a high level of waste treatment will usually be required if the high quality of the water found in recreation areas is to be protected.

Only water-based recreation is considered as a waste source in this section. Although outdoor recreation in the Region covers a wide range of activities, much of the recreation use takes place in municipal parks, sports stadiums and other outdoor community recreation areas that are served by public sewers. Recreation use is also widespread in many rural and remote places because of the outstanding natural setting of the Region and the availability of public recreation areas. However, due to the remoteness to water of many of these areas only those recreation activities classified as water-based, (swimming, water-skiing, boating and fishing) are used in this appendix as sources of water pollution.

Table 25 - WATER-BASED RECREATION - 1965 1/

	Annual Participation in Recreation Days 2/
Lower Main Stem Subregion	11,432,000
Little Colorado Subregion	5,320,000
Gila Subregion	21,180,000
Lower Colorado Region	37,932,000

1/ Sources: Recreation Appendix.
2/ A recreation day is defined as a visit by an individual to a recreation area for recreation purposes during a significant portion or all of 24-hour day.

Attendance data for public recreation areas where opportunities for water-related recreation are the primary attraction provide a breakdown of the day use and overnight use of facilities. The data, supplied by the Recreation Workgroup, are summarized in Table 26.

Table 26 - DAY AND OVERNIGHT USE OF WATER-RELATED RECREATION AREAS

	Day Use	Overnight Use
Lower Main Stem Subregion	80%	20%
Little Colorado Subregion	60	40
Gila Subregion	75	25
Lower Colorado Region	75%	25%

Waste loads from recreational activities are calculated on the assumption that the day and overnight use of private facilities follows this same pattern.

Waste surveys at campgrounds indicate that per capita BOD loads from overnight campers will be about one-half of the contribution from municipal domestic sewage.[16] Dissolved solids and phosphorus in campground wastes are estimated to be about one-fourth of the amount in normal domestic wastes. Studies at day-use recreation areas have shown that per capita BOD production is about one-tenth of the level for municipal domestic wastes. The phosphorus content of wastes at day-use areas has been found to be only about one-fortieth of that normally found in domestic sewage. The low phosphorus content is indicative of the fact that much of the phosphates in domestic wastes comes from detergents and detergent use is considerably less at day-use recreational facilities. TDS is assumed to be present in wastes from day-use activities in the same proportion that BOD and TDS were found in overnight wastes.

Table 27 - DOMESTIC WASTE PRODUCTION FROM WATER-BASED RECREATIONAL ACTIVITIES - 1965
(tons/year)

	BOD	TDS	P
Lower Main Stem Subregion	180	210	4
Little Colorado Subregion	120	140	3
Gila Subregion	360	420	7
Lower Colorado Region	660	770	14

Centralized waste collection and treatment systems as well as individual disposal facilities may be found at campgrounds, picnic areas, lodges, motels, cabins and trailer courts. Waste disposal at recreation areas is generally by septic tanks, pit privies and vault toilets. Biological secondary treatment units are found at some of the larger recreation sites. Most of the secondary treatment works consists of small "package plants" (constructed from preassembled component units) that provide a relatively high degree of waste removal when properly operated.

There are not sufficient data for a comprehensive evaluation of the amount of wastes reaching surface and ground water sources from recreation activities. There are some known incidents of pollution of recreation waters from domestic wastes. For example, the sprawling construction of recreation homes in the high country of the Region has often resulted in the proliferation of septic tanks along some streams. Drainage from these disposal systems is increasingly becoming a source of pollution of area streams. Oak Creek Canyon, the Mogollon Rim Country, and the White Mountains, in particular, are areas where numerous septic tanks are affecting water quality.(3) The lack of sanitary facilities for the inhabitants of the "Parker Strip" area along the Colorado River near Parker, Arizona, has contributed to the bacteriological and nutrient pollution of the River.(3) The influx of recreation visitors to communities in and near many of the prime outdoor recreation areas and the rapid increase in resident population because of recreation attractions are over-loading some municipal treatment works, thereby adding further to pollution of recreation waters.

Waste disposal problems have increased because of a multitude of mobile recreation waste sources in the form of camping trailers, truck campers, and similar recreation vehicles. Indiscriminate dumping of wastes from these vehicles has occurred, in part because of a lack of adequate facilities for disposal. Major efforts are underway by recreation, health and water pollution control agencies and the oil and gas industry to provide a network of disposal facilities for mobile units.

Watercraft--Pollution from watercraft is believed to be significant although, again, data are not available for a full evaluation of the problem. Both the discharge of domestic wastes from boat toilets and the discharge of partially-burned fuel products are possible sources of pollution.

Some 67,000 boats are registered in the states of Arizona, Nevada, New Mexico, and Utah by the end of 1965.(48) Other data, for the year 1966, show 21,000 boats registered in Imperial, Riverside, and San Bernardino Counties in California.(13) Many of these vessels are used on the main-stem reservoirs of the Colorado River.

Table 28 - BOATING ACTIVITY - 1965 1/

	Annual Participation in Recreation Days
Lower Main Stem Subregion	2,308,000
Little Colorado Subregion	1,071,000
Gila Subregion	3,613,000
Lower Colorado Region	6,992,000

1/ Source: Recreation Workgroup

Generally, recreation watercraft less than 16 feet long are not equipped with toilet facilities. It has been estimated that nationally 80 percent of the boats over 16 feet in length have toilets installed on board.[48] National statistics for pleasure craft and boat registration data for Arizona show that 30 percent of the registered recreational watercraft are greater than 16 feet in length.[48][13] Studies of the duration of trips for recreation vessels with lengths over 16 feet indicate that on most outings the onboard toilets would be used.(48) Small quantities of galley wastes presumedly would also be produced on the larger boats.

Arizona, Nevada, and Utah have specific laws governing waste discharges from watercraft.[48] Arizona prohibits discharges. Nevada requires adequate treatment before discharge. Utah requires holding tanks. In New Mexico the discharge of fecal material from boats is covered by the State's waste disposal regulations.

A study conducted by the Arizona State Department of Health showed only limited compliance with Arizona's requirement for installation and use of on-board equipment.[13] Investigations at 40 marinas in Arizona indicate a need not only for additional facilities but also for better management of existing installations.[13]

Substantial amounts of oil and gasoline are spilled into recreation waters from boat servicing facilities near docking areas. On the average, an estimated 10-20 percent of the fuel used in outboard motors is wasted in the exhaust.[13] Outboard motor fuel is a mixture of oil and gasoline, therefore substantial amounts of oil are also discharged in the exhaust. Laboratory studies of pollutants from outboard motor exhaust indicate that approximately 0.23 pounds of oil, as measured by nonvolatile suspended solids, are wasted per gallon of fuel consumed.[8] The turbulence caused by the propeller creates conditions ideal for dispersion of the waste material into the water.

An estimated 60 percent of the boating activity involved use of power boats. Ninety percent of the powered recreation fleet registered in Arizona is composed of vessels with outboard motors. Based on the estimates of recreation use of power boats, a boat occupancy rate of 2.6 persons per boating party[13] and an average fuel consumption requirement of 9 gallons per boating day[4] and neglecting differences between inboard and outboard motor exhaust characteristics, it is estimated that some 12,000 barrels of oil were carried into Region waters in boat motor exhaust during 1965.

The proliferation of piers and other water-front structures along some reaches of the Lower Colorado River is considered to produce undesirable effects on water quality in that the flow of the river near shore is distorted causing the formation of backwaters wherein trash, debris, etc., can collect and decay, and there is an increased probability of pollution from gasoline, oil, and litter. These factors, in turn, lead to a variety of unfavorable water quality conditions such as the destruction of aesthetic values and the elimination or degradation of waterfowl, wildlife and aquatic habitats. Moreover, the piers are often constructed of materials and in a manner that fosters rapid deterioration and abandonment; thus, adding litter to the water course.

The quantity of normal litter contributed by the average boater during a day of active boating has been estimated as one pound of paper, cans, and bottles, and about one-half pound of garbage.[48] Much of this litter frequently ends up strewn along and in waterways. Dumping of fish entrails in the water or on shore occassionally presents an additional source of pollution.

Like other water-based recreational activities it is the concentration of use during weekends, holidays and vacation periods that makes the effects of boat use on water quality particularly significant. It is during these times that swimming, water skiing and other water-contact recreation reach their peak of activity. The operation of boats in and near these areas presents a potential pollution hazard due to the need for water of high quality for body-contact water sports.

Geologic Sources

Sources of pollution considered in this section include saline and radioactive springs.

Spring flow is an important source of water supply in the Region. Practically all of the usable flow of the Muddy River originates as spring flow in the Upper Moapa Valley. Spring flow to the Verde and Salt Rivers in central Arizona is estimated to be at least 85,000 gpm. Other springs scattered throughout the Region make a substantial contribution to the total water supply.

Salt Springs--Quality of the spring flow varies widely with dissolved solids ranging from less than 100 mg/l to greater than 45,000 mg/l. Most of the springs produce water with a salt content of no more than a few hundred mg/l and provide a water supply that is satisfactory for domestic or irrigation use. There are a few springs that produce water of such high salinity that they are sources of chemical pollution to the streams receiving their effluent. Table 29 lists these springs and their contribution. The location of the springs is shown on the following map. In general, the discharges of the springs included in the tabulation have salinities that are materially higher than the waters into which they discharge.

The largest of these springs is Blue Springs located in the Little Colorado Subregion along the Little Colorado River about 13 miles above the confluence of the Little Colorado and the Colorado Rivers. Rather than a single spring, this is an area with many outlets of widely varying discharge and salinity. This one spring area produces an annual salt load of about 547,000 tons, well over half of the total salt load from all of the listed saline springs.

In the Lower Main Stem Subregion the most significant springs are the La Verkin Springs located on the Virgin River near La Verkin, Utah. Although La Verkin Springs do not produce as large a salt load as Blue Springs, they are a more serious source of local pollution due to the smaller volume of flow in the Virgin River. There is some question as to whether the Littlefield Springs contribute additional salt to the Virgin River, because there is reason to believe that the Virgin River is the source of these springs.

In the Gila Subregion there are only a few scattered springs that may be classed as saline. Of these few springs, the Clifton Hot Springs are the largest and produce a salt load of about 21,500 tons per year.

The total contribution of dissolved salts from eleven springs cited in Table 29 amounts to 712,000 tons. In addition to the listed springs, there are other springs such as Rogers Spring on the Virgin arm of Lake Mead which produces substantial amounts of saline water. The effluent from these springs is dissipated by evapotranspiration by vegetation and evaporation or seep into the ground water without reaching a flowing watercourse.

Radioactive Springs --In addition to being sources of increased salinity, some of the natural springs discharge water containing significant levels of radioactivity. Three major radioactive ground water sources located in the Lower Colorado Region are tabulated in Table 30. Data are based on sampling conducted in late 1966.

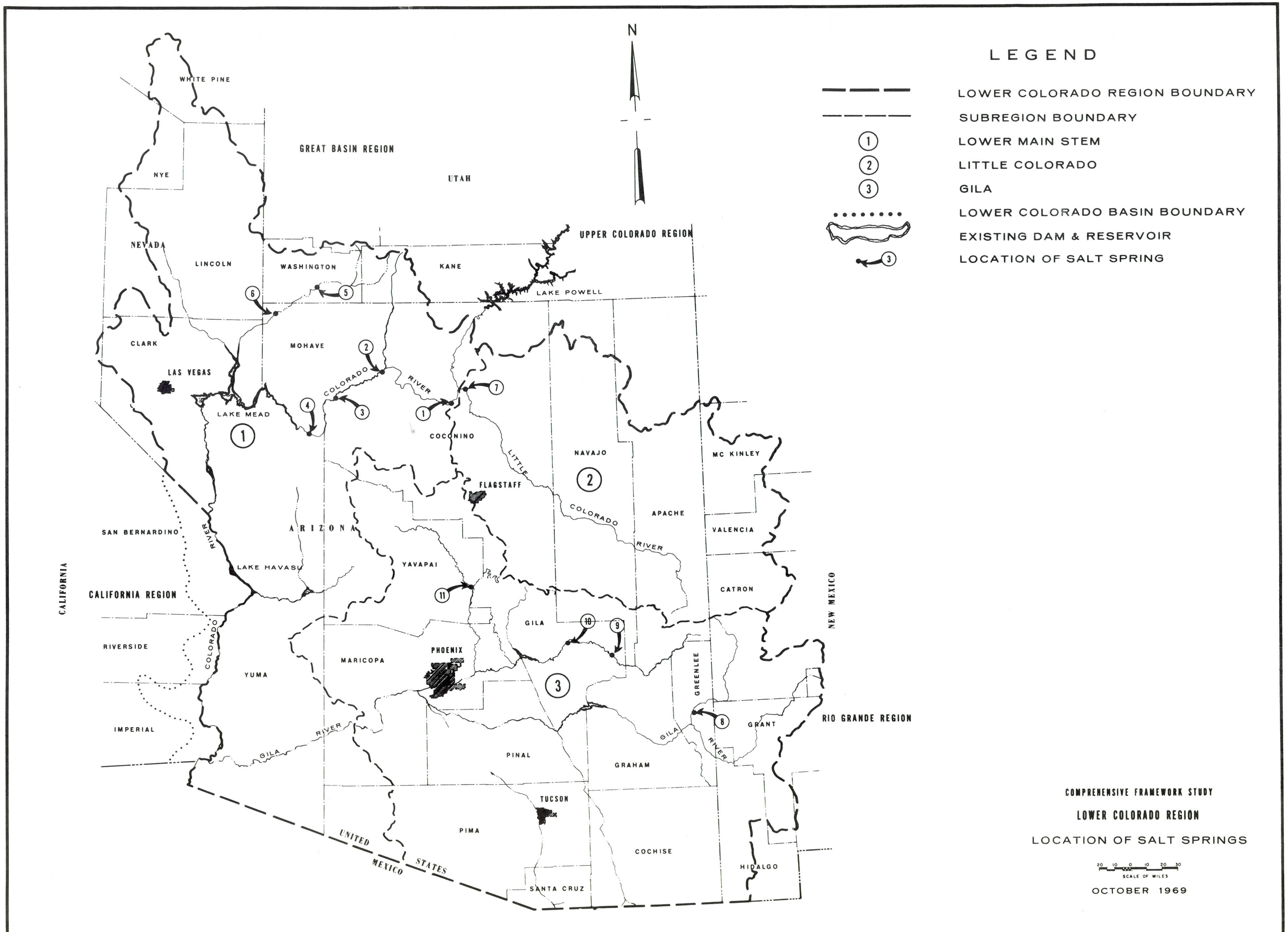

LEGEND
LOWER COLORADO REGION BOUNDARY
SUBREGION BOUNDARY
1 LOWER MAIN STEM
2 LITTLE COLORADO
3 GILA
LOWER COLORADO BASIN BOUNDARY
EXISTING DAM & RESERVOIR
LOCATION OF SALT SPRING
N
GREAT BASIN REGION
UTAH
UPPER COLORADO REGION
NEVADA
WHITE PINE
NYE
LINCOLN
WASHINGTON
KANE
LAKE POWELL
CLARK
LAS VEGAS
MOHAVE
LAKE MEAD
COLORADO
RIVER
COCONINO
LITTLE COLORADO RIVER
NAVAJO
APACHE
MC KINLEY
VALENCIA
CATRON
FLAGSTAFF
ARIZONA
YAVAPAI
SAN BERNARDINO
LAKE HAVASU
CALIFORNIA
CALIFORNIA REGION
RIVERSIDE
IMPERIAL
YUMA
MARICOPA
PHOENIX
GILA
GREENLEE
GRANT
RIO GRANDE REGION
NEW MEXICO
GILA RIVER
PINAL
GRAHAM
TUCSON
PIMA
COCHISE
HIDALGO
SANTA CRUZ
UNITED STATES
MEXICO
COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION
LOCATION OF SALT SPRINGS
SCALE OF MILES
OCTOBER 1969

Table 29 - SALT SPRINGS IN THE LOWER COLORADO REGION

Map No.	Source	Flow (gpm)	TDS (mg/l)	Salt Load (tons per year)
	Lower Main Stem Subregion			
1	Spring	1	44,720	100
2	Spring	25	1,200	7-
3	Vulcan Spring	2,240	884	4,350
4	Springs above Travertine Falls	23	937	50
5	LaVerkin Springs	4,720	10,060	104,000
6	Littlefield Springs	4,490	2,930	29,600
	Subtotal			138,170
	Little Colorado Subregion			
7	Blue Springs	98,750	2,500	547,000
	Subtotal			547,000
	Gila Subregion			
8	Clifton Hot Springs	1,000	9,790	21,500
9	White River Salt Springs	950	2,160	4,500
10	Salt Banks	14	27,200	840
11	Verde Hot Springs	10	3,100	70
	Subtotal			26,910
	Total Lower Colorado Region			712,080

Table 30 - RADIOACTIVITY IN SPRING WATERS

Source	Receiving Stream	Flow	Ra-226 (pg/l)
LaVerkin Springs	Virgin River	4720	37
Rogers Spring		900	0.19
Littlefield Springs	Virgin River	4490	0.61

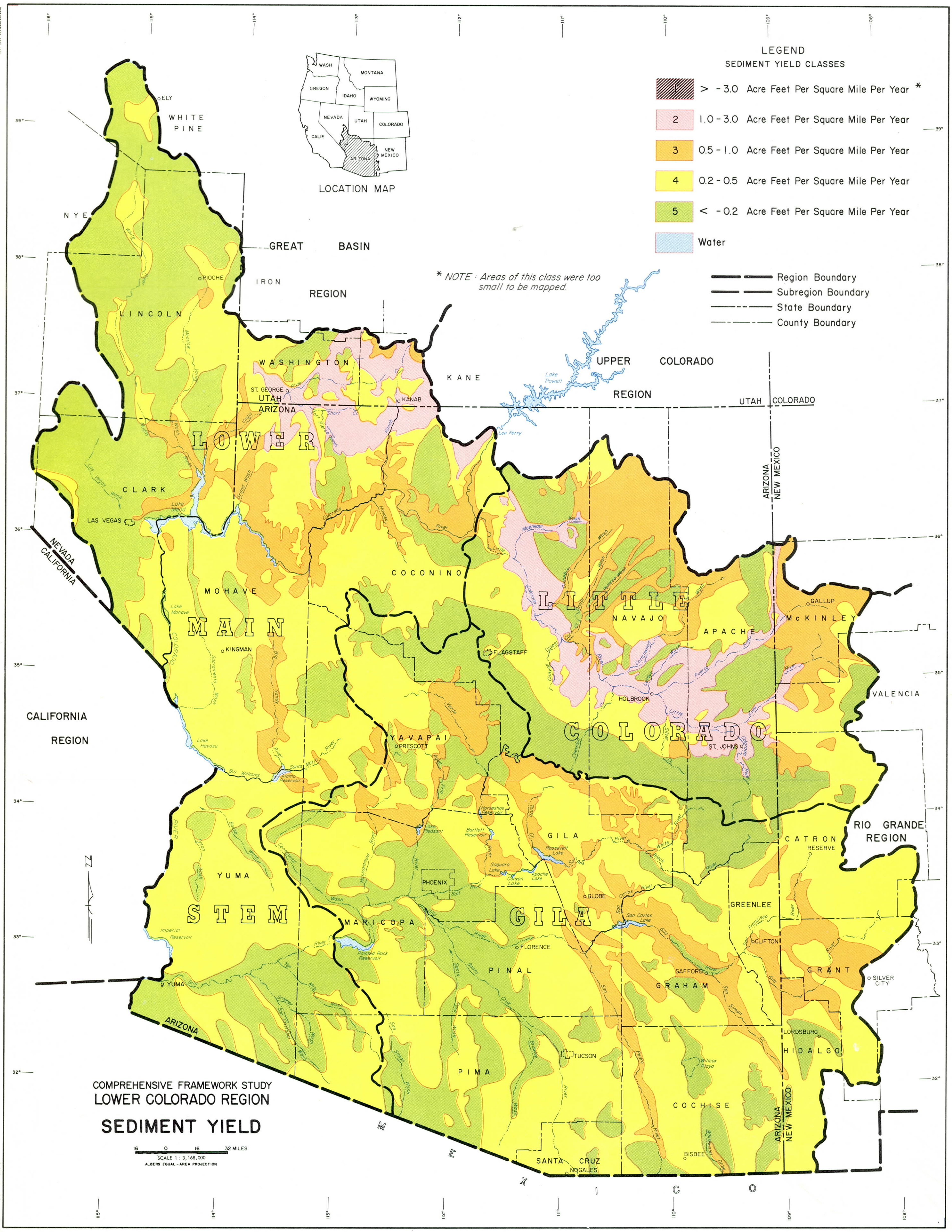
The LaVerkin Springs has a substantial impact on the radioactivity of the receiving stream. The radium-226 concentration of the Virgin River during the period September-October 1966 increased from 0.10 picograms per liter at Virgin, Utah, to 0.45 pg/l at Littlefield, Arizona. Virtually all this increase is due to LaVerkin Springs.

Land Erosion and Sedimentation

A detailed discussion of the current conditions of the watersheds in the Region including the present status of erosion and sedimentation is presented in the Watershed Management Appendix.

The Sediment Yield Map shows four sediment yield classes of annual yield in acre-feet per square mile. This map represents sediment yield unadjusted for cultural activities. For watersheds of 2,000 square miles or less the map is adequate for computing the volume of sediment leaving the basin. For larger areas, such as the subregions, man's diversion and storage of the steamflow have reduced stream discharge and, therefore, reduced stream sediment transport ability to the point the map does not represent actual yields.

Table 31 shows the amount and percentage of sediment yield classes by subregion. It is interesting to note that nearly half the area of the Region is sediment yield class 4. Also, no sediment yield class 1 was mapped in the Region and no sediment yield class 2 was mapped in the Gila Subregion.


LEGEND
SEDIMENT YIELD CLASSES
1 > - 3.0 Acre Feet Per Square Mile Per Year *
2 1.0 - 3.0 Acre Feet Per Square Mile Per Year
3 0.5 - 1.0 Acre Feet Per Square Mile Per Year
4 0.2 - 0.5 Acre Feet Per Square Mile Per Year
5 < - 0.2 Acre Feet Per Square Mile Per Year
Water
* NOTE: Areas of this class were too small to be mapped.
Region Boundary
Subregion Boundary
State Boundary
County Boundary
LOCATION MAP
GREAT BASIN REGION
UPPER COLORADO REGION
CALIFORNIA REGION
RIO GRANDE REGION
LOWER MAIN STEM
LITTLE COLORADO
GILA
UTAH
ARIZONA
NEVADA
CALIFORNIA
NEW MEXICO
COLORADO
MEXICO
LAS VEGAS
KINGMAN
FLAGSTAFF
PRESCOTT
PHOENIX
TUCSON
YUMA
GLOBE
FLORENCE
SAFFORD
BISBEE
NOGALES
HOLBROOK
ST. JOHNS
GALLUP
KANAB
ST. GEORGE
PIOCHE
ELY
CLIFTON
SILVER CITY
LORDSBURG
COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION
SEDIMENT YIELD
SCALE 1 : 3,168,000
ALBERS EQUAL - AREA PROJECTION

M7-S-21431D-N

Table 31 - ACREAGE AND PERCENT OF SEDIMENT YIELD CLASSES

Subregion	Sediment Yield Classes 1/									
	1		2		3		4		5	
	Ac*	%	Ac*	%	Ac*	%	Ac*	%	Ac*	%
Lower Main Stem	0	0	1,955	2.2	3,321	3.7	17,759	19.7	12,910	14.3
Little Colorado	0	0	3,167	3.5	3,861	4.3	4,866	5.4	5,358	6.0
Gila	0	0	0	0	5,467	6.1	21,517	23.9	9,806	10.9
Lower Colorado Region	0	0	5,122	5.7	12,649	14.1	44,142	49.0	28,074	31.2

*Thousands

1/ The five classes of sediment yield expressed in acre-feet per square mile per year are:

Class 1 - More than 3.0
Class 2 - 1.0-3.0
Class 3 - 0.5-1.0
Class 4 - 0.2-0.5
Class 5 - Less than 0.2

Sediment yields shown on the map are the average annual values and cannot be correlated to individual sediment concentrations measured in a stream. Concentrations are measurements made at a given time and due to fluctuations in the daily discharge may not represent the average annual concentration.

Kanab Creek at Fredonia, an intermittent stream, has had sediment concentrations as high as 700,000 ppm. This would be sediment yield class 1. The watershed of Kanab Creek is sediment yield class 2. If all stages of flow for an extended period were considered the average concentration should be compatible with the predicted yield.

The Virgin River at Littlefield, a perennial stream, has an annual load which is sediment yield class 4. The sediment yield class of the Virgin River watershed is also class 4. So, where annual loads are used reasonably accurate estimates of sediment in a stream can be made from the Sediment Yield Map.

Suspended sediment data for streams are presented in the Present Water Quality section.

Accidental Spills

The accidental discharge of liquid wastes from mining operations has resulted in pollution of the San Francisco and Gila Rivers.[59]

Incidents of accidental pollution from other sources have not been reported. The possibility of accidental spills exists from transportation accidents, pipeline breaks, process plant breakdown and failure of other waste treatment and retention works.

Present Water Quality

Except for the main stem of the Lower Colorado River only limited information is available describing water quality in the Lower Colorado Region. The discussion of the quality presented herein is based on published and unpublished USGS data, EPA water quality surveillance data, the "Report on Cooperative Water Resource Inventory-Arizona" [38] and various project reports by the Bureau of Reclamation, the Department of the Interior Report "Quality of Water-Colorado River Basin,"[33] and various other sources of information.

Mineral Quality

Total Dissolved Solids--The Colorado River transports nearly 8,200,000 tons of dissolved solids into the Region annually from the Upper Colorado Region according to data for the 1941 to 1966 period of record modified to 1966 conditions.[33] For the longer 1914 to 1965 period it is estimated that the average annual salt load carried by the Colorado River at Lee Ferry amounts to about 8,700,00 tons. Concentrations of dissolved solids corresponding to the 1941 to 1966 period for locations on the Colorado River are tabulated below:

Table 32 - AVERAGE DISSOLVED SOLIDS CONCENTRATIONS IN THE COLORADO RIVER

Location	TDS (mg/l)
At Lee Ferry, Arizona	586
Near Grand Canyon, Arizona	647
Below Hoover Dam	734
Below Parker Dam	726
At Imperial Dam	839

Since the closure of Glen Canyon Dam in 1963, the wide variations in the quality of inflowing waters have been dampened due to the effects of storage and mixing in the reservoir. Prior to closing, however, concentrations above Lake Mead ranged from as high as 1,900 mg/l during low flows to less than 210 mg/l at high flow. Flow regulation by downstream impoundments has similarly reduced the variability in quality of the remainder of the Colorado River.

Waters entering the Lower Colorado Region are of the calcium-sodium-sulfate type. Little change in the proportions of chemical constituents is noted downstream to Imperial Dam. Irrigation return flows in this reach do not change the chemical composition of the receiving water. Much of the increase in concentrations in this part of the River is attributed to evapotranspiration, thus not much change in the chemical pattern occurs. Return flows from irrigation drains downstream from Imperial Dam cause the Colorado River water to become predominately a sodium-chloride type for the remainder of the River's course to the international border.

The quality of the waters discharged from tributary streams in the Lower Main Stem Subregion is slightly to moderately saline but is generally satisfactory for irrigation on the soils irrigated and for the crops grown in the area. Kanab Creek contributes small flows with TDS concentrations averaging about 1,100 mg/l. The Virgin River adds about 350,000 tons of dissolved salts to the Colorado River yearly. Dissolved solids in the Virgin River average over 1,600 mg/l, consisting mainly of sulfates, chlorides, and sodium. The high salinity of the Virgin River is primarily due to saline flows from LaVerkin Springs.

Discharge from the Muddy River is small and slightly saline. Flow in Las Vegas Wash at its mouth is mostly municipal and industrial effluents from the Las Vegas, Nevada area. The wash generally carries a heavy salt load averaging over 5,000 mg/l during 1967. The average mineral quality of the Bill Williams River ranges from about 500 to 700 mg/l of TDS.

Good-quality water is found in the headwaters of the Little Colorado River above Lyman Reservoir located upstream from St. Johns, Arizona. Limited sampling indicates that surface waters in this area contains dissolved solids at concentrations of less than 500 mg/l. Most of the runoff from above the reservoir is impounded for irrigation. Flow in the river below the reservoir primarily consists of saline waters from seeps and springs. Consequently, the quality of the water in the river below Lyman Reservoir is slightly saline with TDS concentrations frequently exceeding 1,000 mg/l.

Better-quality water from the Zuni River dilutes the Little Colorado River flows to about 400 mg/l TDS. The upper reaches of the Puerco River in New Mexico produce waters varying in quality from about 500 to 1,000 mg/l of dissolved salts. The mineral quality of the Little Colorado River in the Holbrook-Winslow reach varies from about 200 to 400 mg/l TDS. Downstream at Cameron, long-term data indicate an average dissolved solids concentration of 700 mg/l. The annual discharge at Cameron carries an average 130,000 tons of dissolved solids. Moenkopi Wash contributes flows with TDS levels over 1,000 mg/l.

The quality of the Little Colorado River at its confluence with the Colorado River deteriorates to about 1,500 mg/l of dissolved salts. Most of this increase is from the discharge of the Blue Springs, located near the mouth of the Little Colorado. The salt content of the water from the springs generally averages about 2,500 mg/l, with chloride concentrations over 1,000 mg/l. The water of the Little Colorado River at its mouth is of the sodium-chloride type.

The chemical quality of the Gila River system varies considerably throughout the Gila Subregion. Surface waters at the head of the Gila River generally contain less than 500 mg/l TDS. Sampling conducted during 1965 indicated a mean TDS concentration of 150 mg/l for 28 samples collected from the Gila River at a point near Gila, New Mexico.

The salinity of the Gila River is increased by substantial inputs of sodium and chloride from the San Francisco River, a major upstream tributary. Dissolved solids in the San Francisco River range from about 200 to 1,200 mg/l. Intermittent flows from the San Simon River contain dissolved solids in concentrations of from 500 to 900 mg/l. The quality of the San Carlos River varies over a wide range depending on the quantity of flow, but it is suitable for irrigation of salt tolerant and moderately salt tolerant crops.

The Gila River near Bylas at the lower end of Safford Valley, an area of irrigated agriculture, increases in salinity to about 1,000 mg/l with sodium and chloride the predominate ions in the water. A marked increase in the dissolved salt content of the Gila River is evident downstream to Bylas. A study conducted by the State of Arizona in 1967 and 1968 showed that mean TDS concentrations increased from 230 mg/l at the New Mexico-Arizona stateline to 1,370 mg/l near Bylas; a six-fold increase in a 113- mile reach. Maximum readings at these stations were 360 and 4,730 mg/l respectively.(9)

Erratic flows from the San Pedro River have been reported to be of better-than-average quality. Daily sampling of the Gila River at Kelvin, Arizona during water years 1964-1966 provides TDS data ranging from a minimum 380 mg/l to a maximum 4,300 mg/l; the mean soluble salt content for this period was 900 mg/l. Very little flow is to be found in the Gila River between Ashurst-Hayden Dam near Florence, Arizona and its confluence with the Salt River near Phoenix.

The Salt River and its major tributary, the Verde River, supply most of the surface water used in the Metropolitan Phoenix area. Good-quality water is found in the upper reaches of the Salt-Verde watershed. The mineral quality remains good throughout the course of the Verde River, but going downstream the Salt River increases appreciably in total dissolved solids and chlorides. Principal constituents in the water conveyed to Phoenix are chlorides, sodium, and bicarbonates. Data for water years 1964 through 1966 show a mean TDS concentration for the Verde River below Bartlett Dam of 250 mg/l with a high of 550 and a low of 150 mg/l. The Salt River below Stewart Mountain Dam during the same period showed a quality ranging in TDS from 400 to 790 mg/l with 630 mg/l as the mean level.

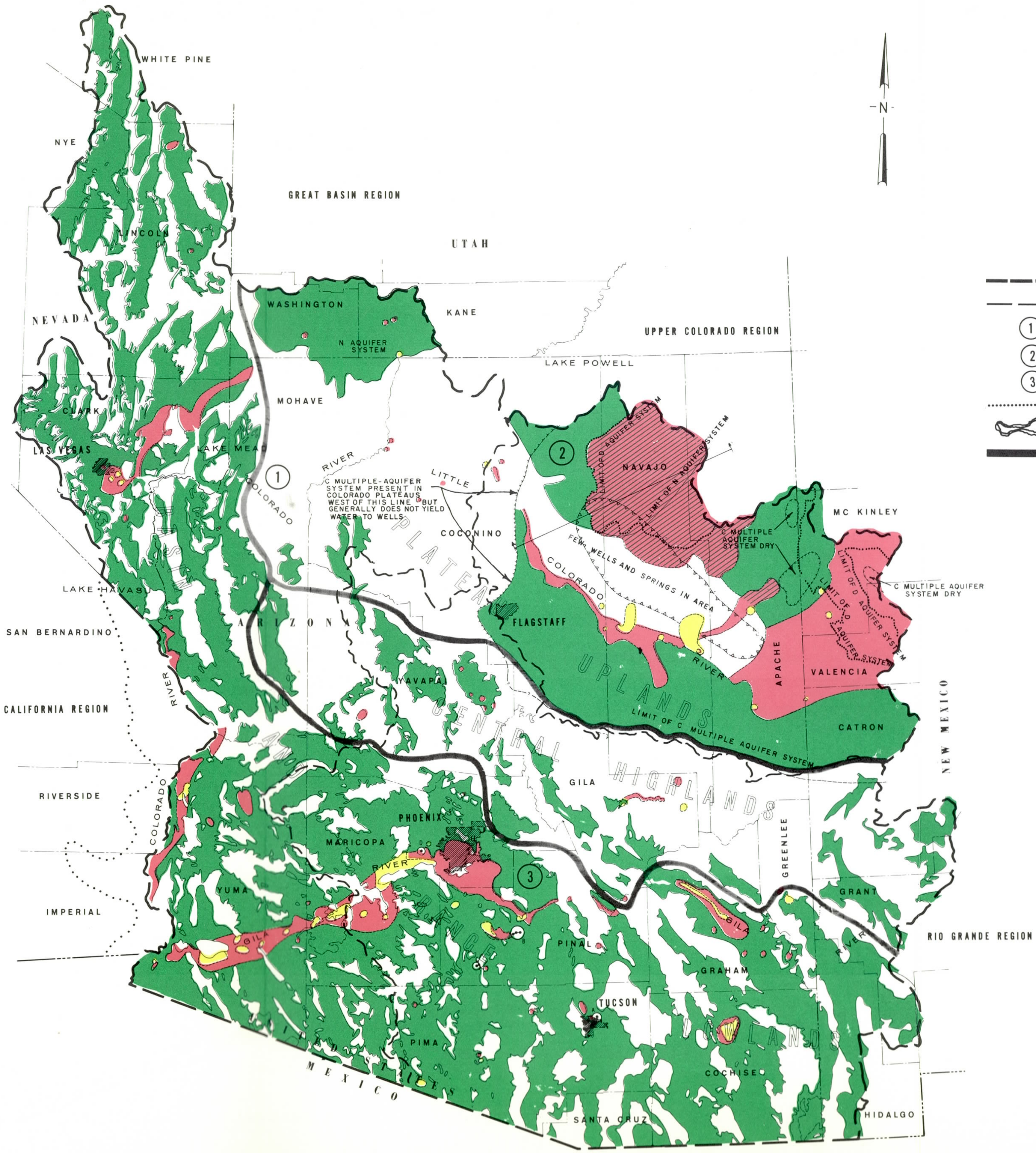
Municipal and industrial effluents and other inflows to the Gila River in the Phoenix area are diverted in the vicinity of Buckeye, Arizona for irrigation. One such diversion is at Gillespie Dam, where data for water years 1964-66 indicate moderately saline water. The mean dissolved solids concentration at this point was 3,100 mg/l. A low of 260 mg/l was observed along with a high of 7,400 mg/l. The Gila River below Gillespie Dam carries only infrequent storm flows.

Ground water in the alluvial deposits in the basin and range lowlands contains from less than 100 to more than 100,000 mg/l of dissolved solids. Dissolved solids concentrations in water from the wells in this area vary not only with the location of the well but with its depth, as shown on Figure 2. This is because the most important control of the water quality in the lowlands is the mineralogical makeup of the deposits within which the water is found. These deposits are alluvial in nature and are made up of weathering products from the surrounding mountain masses. A particular deposit may be high in fluoride if derived from igneous rocks or high in sodium or calcium if deposited respectively in a marine environment or in a playa. The map, "Distribution of Dissolved Solids in Ground Water," shows the distribution of dissolved Solids concentrations based on samples from wells in the Region. Most of the deposits in the basin and range lowlands contain water having less than 1,000 mg/l.

The chemical quality of the water of the plateau uplands varies greatly both areally and with depth. See Figure 3. The dissolved solids content ranges from 90 to more than 60,000 mg/l. Similar to the water occuring in the alluvial aquifers in the basin and range lowlands, the quality of water from the sedimentary rocks in the uplands reflects influences of deposits associated with sandstone and limestone. A wide area in the plateau uplands contains water having between 1,000 and 3,000 mg/l of dissolved solids. The poorest quality water occurs, in general, north of the Little Colorado River. In this area water from the Coconino sandstone and other locally water-yielding sandstone beds, and from the alluvium contains more than 10,000 mg/l of dissolved solids.

Most of the chemical quality data available for the highlands indicate that the ground water generally contains less than 1,000 mg/l of dissolved solids. Water quality undoubtedly varies from good to poor throughout the highlands depending upon the aquifer within which it occurs. Several springs yield saline water to streams. Some of these springs were listed in the Geologic Sources of Pollution section. One of these, Clifton Hot Springs, yields water from the alluvium along the San Francisco River. The water contains more than 9,000 mg/l of dissolved solids. Its high temperature and mineralization indicate that its source is deep seated.

Municipal, industrial and agricultural use of ground and surface waters of the Region are significantly influenced



LEGEND

DISSOLVED SOLIDS (MG/L)	SPECIFIC CONDUCTANCE (MICROMHOS AT 25°C)
LESS THAN 1,000	LESS THAN 1,700
1,000 TO 3,000	1,700 TO 5,000
MORE THAN 3,000	MORE THAN 5,000

NOTE: IN THE PLATEAU UPLANDS THE N MULTIPLE-AQUIFER SYSTEM YIELDS WATER THAT GENERALLY CONTAINS LESS THAN 1,000 MG/L OF DISSOLVED SOLIDS. WHERE HATCHED IN GREEN, THE N MULTIPLE-AQUIFER SYSTEM LIES BENEATH THE D MULTIPLE-AQUIFER SYSTEM AND OTHER WATER-BEARING STRATA AND CONTAINS WATER HAVING LESS THAN 1,000 MG/L. WELLS THAT TAP THE D MULTIPLE-AQUIFER SYSTEM YIELD WATER THAT CONTAINS GENERALLY FROM 1,000 TO 3,000 MG/L OF DISSOLVED SOLIDS. WELLS THAT TAP THE C MULTIPLE AQUIFER SYSTEM YIELD WATER THAT CONTAINS FROM ABOUT 200 TO MORE THAN 25,000 MG/L OF DISSOLVED SOLIDS. THE MAIN WATER-BEARING UNITS IN THE WIDESPREAD C AQUIFER SYSTEM ARE THE COCONINO SANDSTONE IN THE LITTLE COLORADO RIVER VALLEY AND AREAS TO THE SOUTH AND WEST. THE DE CHELLY SANDSTONE IN THE DEFIANCE PLATEAU AREA AND THE GLORIETA SANDSTONE IN NEW MEXICO.

WELLS IN THE HATCHED AREA, OTHER THAN THOSE IN THE N, D, AND C MULTIPLE-AQUIFER SYSTEMS, YIELD WATER THAT CONTAINS LESS THAN 3,000 MG/L OF DISSOLVED SOLIDS, DEPENDING ON THE AQUIFER OR COMBINATION OF AQUIFERS PENETRATED BY THE WELLS

AREA IN THE BLACK MESA BASIN WHERE WELLS THAT TAP THE COCONINO SANDSTONE YIELD WATER THAT CONTAINS MORE THAN 25,000 MG/L OF DISSOLVED SOLIDS

A — A' LINE OF SECTION SHOWN ON FIGURE

B WELL OR WELLS FOR WHICH SEDIMENT TYPES AND WATER QUALITY ARE GIVEN ON FIGURE

LOWER COLORADO REGION BOUNDARY

SUBREGION BOUNDARY

1 LOWER MAIN STEM

2 LITTLE COLORADO

3 GILA

LOWER COLORADO BASIN BOUNDARY

EXISTING DAM & RESERVOIR

PHYSIOGRAPHIC PROVINCE BOUNDARY

COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION
DISTRIBUTION OF DISSOLVED SOLIDS IN GROUND WATER

30 0 30 60 90
SCALE IN MILES

OCTOBER 1969

GPO 856-790

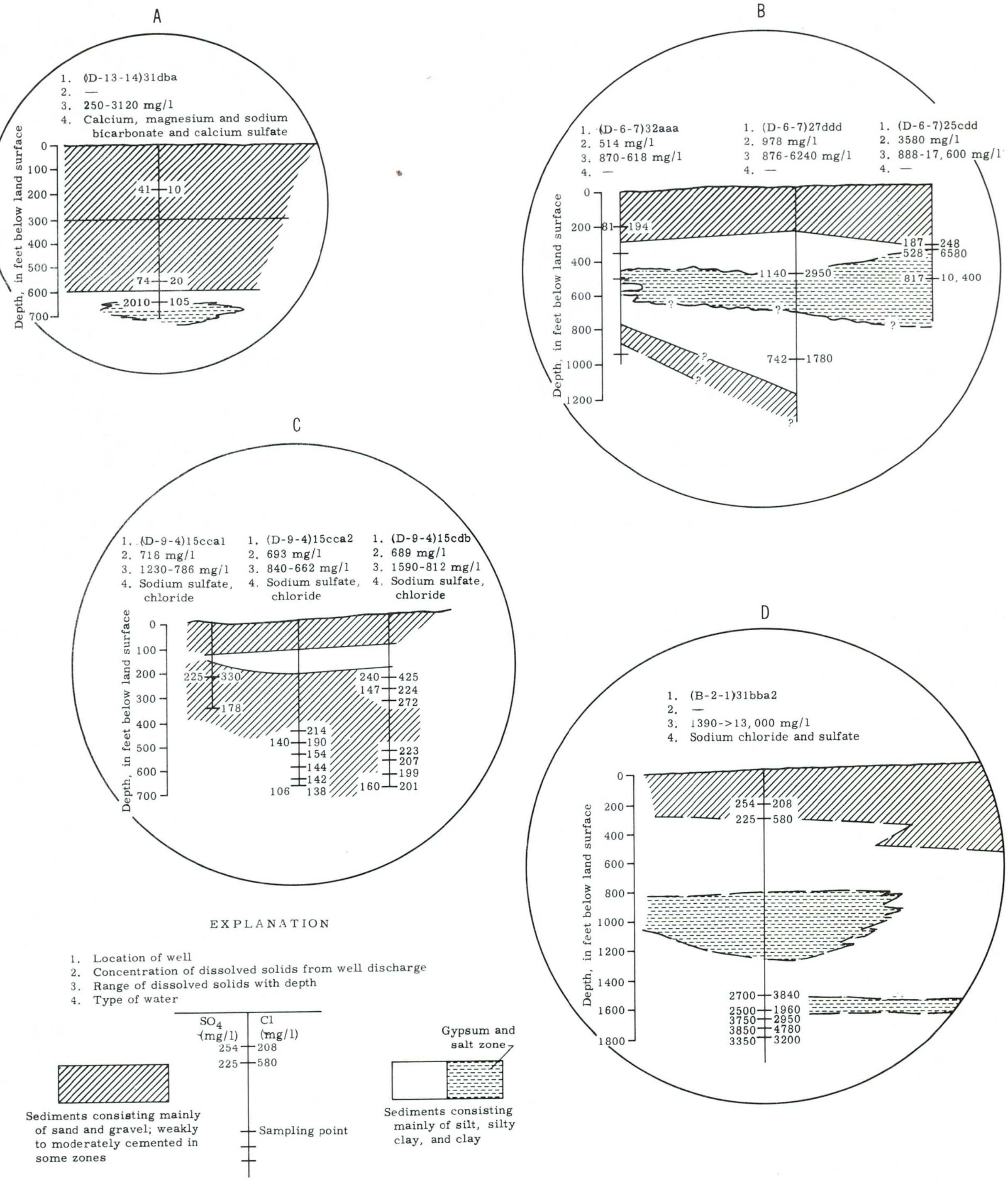
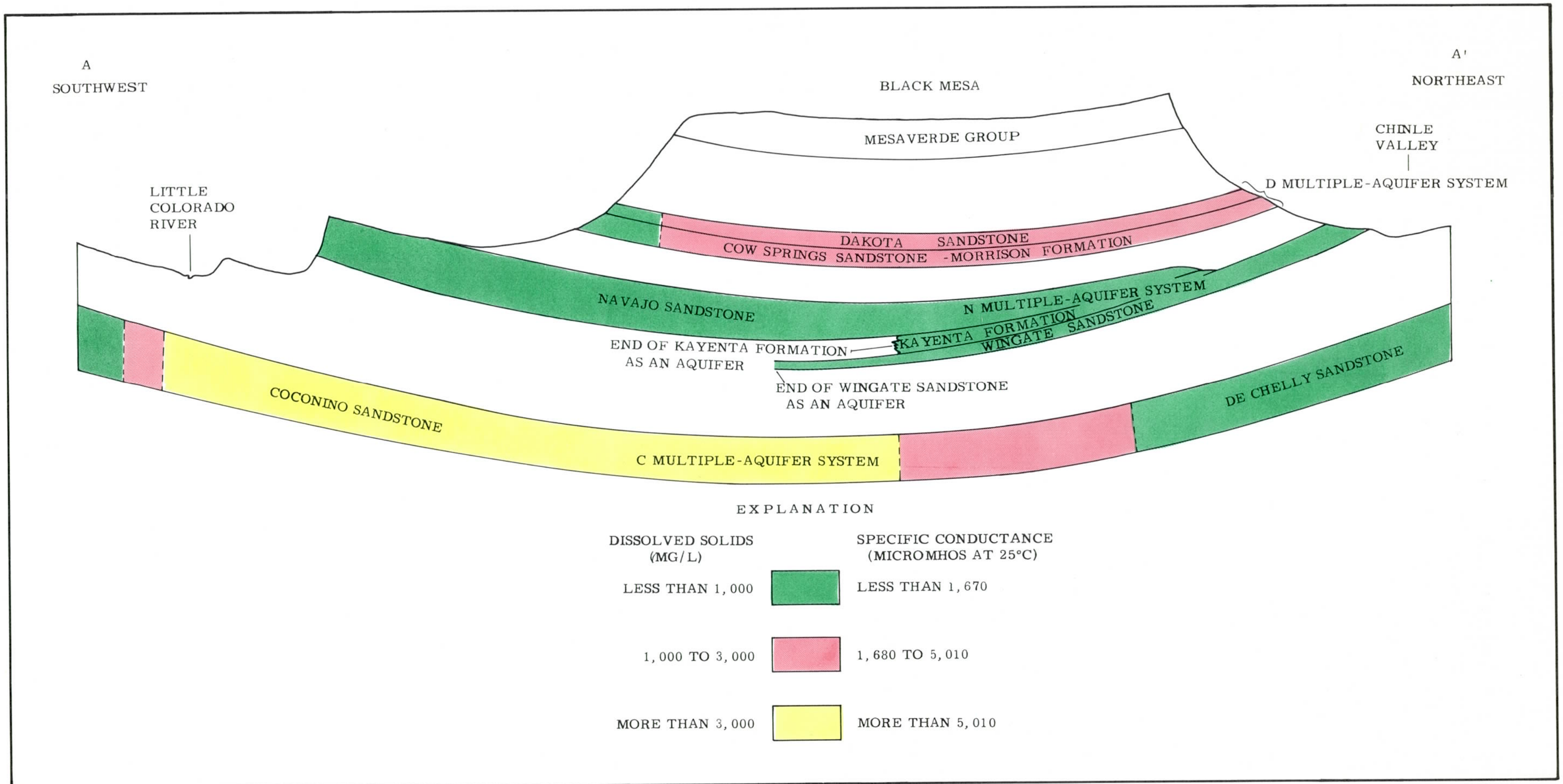


FIGURE 2 --DIAGRAMS SHOWING SEDIMENT TYPES AND CHANGES IN THE QUALITY OF THE WATER FROM SELECTED WELLS IN THE BASIN AND RANGE LOWLANDS.

GPO 856-789



LENGTH OF SECTION ABOUT 110 MILES

NO VERTICAL SCALE

FIGURE 3 --HIGHLY DIAGRAMMATIC CROSS SECTION A-A' IN THE PLATEAU UPLANDS SHOWING THE GENERALIZED QUALITY OF WATER FROM THE C, N, AND D MULTIPLE-AQUIFER SYSTEMS.

by the mineral quality of the water supply. No specific limitations for salinity were set in the various state standards, pending additional study aimed at recommendations for salinity improvements. The Public Health Service Drinking Water Standards(27) recommend a maximum concentration of 500 mg/l of dissolved solids in domestic supplies. This limit is based on the taste and laxative properties of dissolved solids in water. However, in the absence of better quality water most people adjust to water containg substantially higher concentrations of dissolved minerals. Adherence to the drinking standards would restrict domestic use of surface and ground supplies in many parts of the Region.

Water with a dissolved solids concentration under 2,500 mg/l has been classified as acceptable to good for livestock drinking water and water with higher concentrations has been reported satisfactory for use. Accordingly, most of the surface and shallow ground waters are suitable for stock watering. The suitability of mineralized water for industrial requirements depends on the specific use of the water as quality criteria for cooling, processing, steam generation, and other uses vary considerably. Treatment and dilution with better quality water is required to meet some industrial needs.

According to the U.S. Salinity Laboratory classification system(21) most of the major irrigation supplies would be considered to present a medium to high salinity hazard to irrigation crops. With moderate leaching these waters are suitable for most irrigated agriculture in the Region. The Colorado River from Lee Ferry to Imperial Dam has a salinity content classified as presenting medium to high salinity hazards to irrigated agriculture. At the northerly international boundary the Colorado River is classified as a very high salinity irrigation supply. Elsewhere in the Lower Main Stem Subregion the Virgin River and Las Vegas Wash are rated as very high salinity waters.

Most of the irrigated lands in the Little Colorado Subregion are located in the upper reaches of streams where applied water has a low or medium salinity level. However, the Puerco River has a high salinity hazard. In the Gila Subregion the San Francisco and San Simon Rivers are designated as high salinity irrigation supplies. The Gila River is classified as ranging from low to medium above irrigated lands in Safford Valley. Below Safford Valley the salinity hazard is high. The Verde River is classified as low to medium salinity water throughout its course, but downstream reaches of the Salt River contain high salinity irrigation water. Return flows diverted for irrigation at Gillespie Dam are classified as very high salinity water, but the poor quality surface water is mixed with better quality ground water.

Most ground water supplies used for irrigation are classified as medium to high salinity waters. Ground water underlying some irrigable areas is unsuitable for irrigation. These areas of high dissolved solids in ground water are shown in the drawing depiciting the distribution of dissolved solids in ground water.

Sodium--The sodium content is important because it may affect the suitability of the water as an irrigation supply. The amounts of sodium found in Regional waters are well below levels that might interfere with other uses.

Waters with high sodium hazards may affect soil structures, infiltration and permeability. The U. S. Salinity Laboratory classifies the sodium hazards to soil by the use of a sodium adsorption ratio (SAR).

The sodium adsorption ratios of surface waters at most points of irrigation diversion are less than 10 indicating a low sodium hazard. Most of the ground water used for irrigation also has a SAR of less than 10. The use of water classified as presenting medium salinity and low sodium hazards would require moderate leaching under average soil conditions in order to prevent the development of harmful levels of sodium in the soil.

Medium-sodium water may present an appreciable sodium hazard if used on some soils. Water diverted at Gillespie Dam has SAR's falling within the 10 to 18, medium-sodium hazard, range. Ground waters along the lower Gila River in the Wellton-Mohawk Irrigation and Drainage District and in the Las Vegas, Nevada area are classified as medium-sodium hazard supplies. In the Gila Subregion ground water with SAR values greater than 10 occur in Graham County, Arizona near Casa Grande and Stanfield in Pinal County, and near Chandler in Maricopa County. Other areas of medium-sodium hazard ground water in Maricopa County include the Rainbow Valley, Hassayampa, Arlington, Tonopah and Tolleson areas.

Boron--Surface waters contain minimal concentrations of boron, except for the Colorado River at Yuma, Arizona, where concentrations have reached 0.4 mg/l, the critical level for citrus crops grown in that area. A high boron content will also be found in the waters impounded at Gillespie Dam on the Gila River where concentrations average more than one mg/l.

Ground waters having boron concentrations greater than 0.5 mg/l occur extensively in the southern half of the Region.

Many wells in the greater Phoenix area have boron concentrations varying between 0.5 mg/l and 1 mg/l. Boron concentrations in ground water exceed 1 mg/l near Palo Verde, in a large area south of Gila Bend, and in many small areas along the Salt and Santa Cruz Rivers. Boron concentrations vary between 1 and 2 mg/l in ground water south of the Gila River for nearly its entire length in Yuma County. The high-boron water is used selectively on boron-tolerant crops or mixed with better quality water because of its toxicity to many plants.

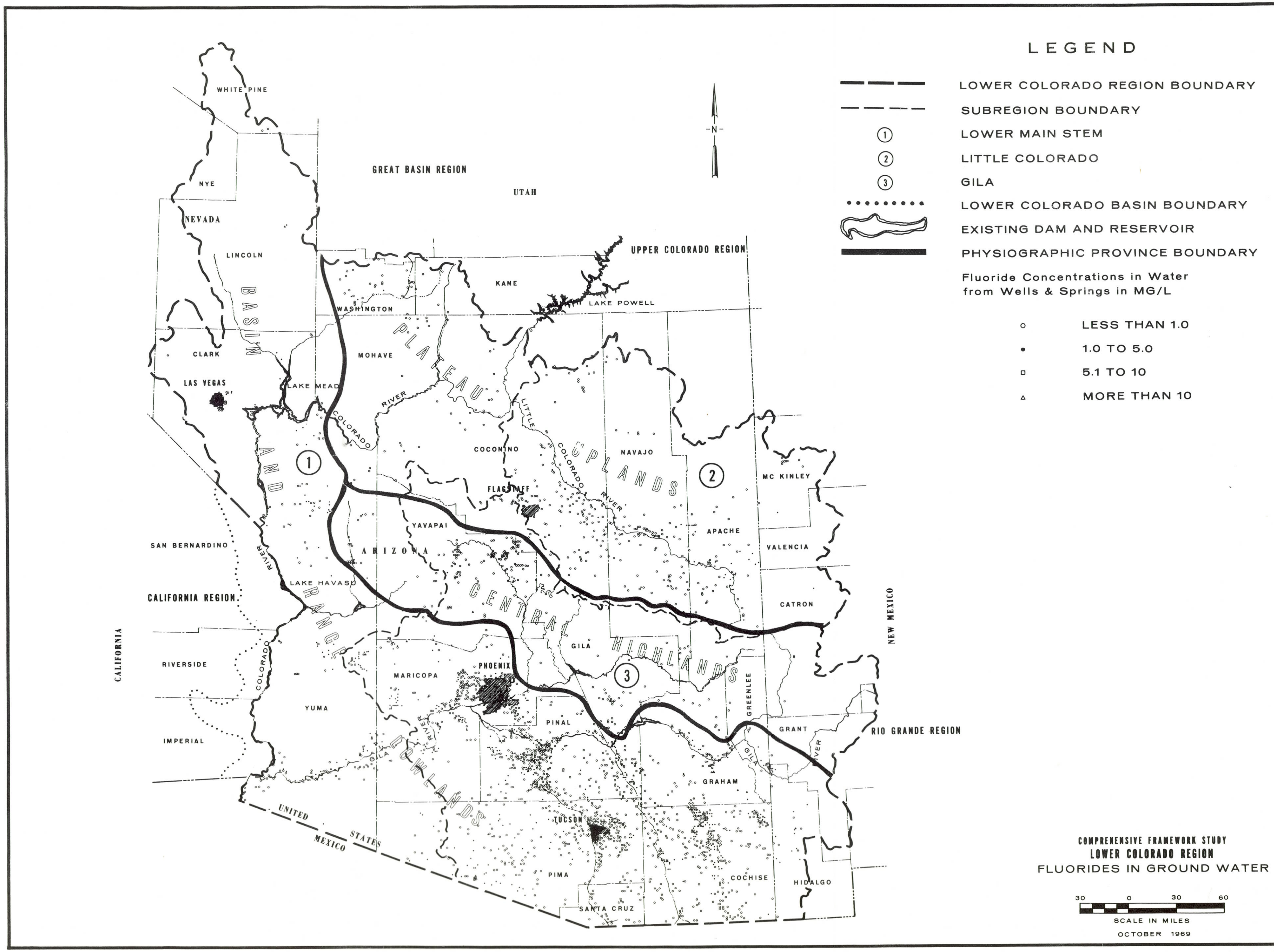
Fluorides--Fluorides present in some surface and ground waters restrict their use as domestic supplies. Fluoride in excess of 1.5 mg/l may cause mottling of the enamel of children's teeth. Concentrations exceeding twice this amount are often found in the Little Colorado River. Concentrations of fluorides in the Gila River range upward to a high of 4 mg/l at Gillespie Dam. High concentrations may also be observed at the head of the Gila River; a maximum of 3.0 was noted during the period 1964-66 at Gila, New Mexico. Fluoride concentrations in the Salt River System are within recommended limited. Fluorides in the Colorado River are generally less than 0.5 mg/l.

Fluoride concentrations in ground water in a large part of the area north of the Little Colorado River exceed the recommended level. In some of these areas fluoride concentrations are more than 4 mg/l. A high fluoride content is also found in ground waters in southeastern Arizona and near Tucson. In some ground water areas in southeastern Nevada over 2 mg/l of fluoride is present.

The distribution of fluorides in ground waters is shown on the map "Fluorides in Groundwater".

Nitrates--A maximum of 45 mg/l of nitrates is recommended by the Public Health Service for drinking supplies as waters with higher concentrations present a health hazard when consumed by infants. Concentrations of nitrates in surface waters are generally less than 5 mg/l. Peak nitrate concentrations of 23 and 77 mg/l have been noted in the Gila River at Kelvin, Arizona and Gillespie Dam, respectively. Nitrates in the Salt River are well within Public Health Service limits, averaging about 2 mg/l.

Concentrations of nitrates are generally small in water from drilled wells and springs. Water samples from some dug wells in northern Arizona have been found to contain more than 45 mg/l of nitrates. Nitrates in shallow ground waters in some areas near Tucson have increased to over 45 mg/l, apparently because of the use of municipal sewage effluents for irrigation.[6]



LEGEND
LOWER COLORADO REGION BOUNDARY
SUBREGION BOUNDARY
1 LOWER MAIN STEM
2 LITTLE COLORADO
3 GILA
LOWER COLORADO BASIN BOUNDARY
EXISTING DAM AND RESERVOIR
PHYSIOGRAPHIC PROVINCE BOUNDARY
Fluoride Concentrations in Water from Wells & Springs in MG/L
LESS THAN 1.0
1.0 TO 5.0
5.1 TO 10
MORE THAN 10
GREAT BASIN REGION
UTAH
UPPER COLORADO REGION
CALIFORNIA REGION
RIO GRANDE REGION
NEVADA
CALIFORNIA
ARIZONA
NEW MEXICO
UNITED STATES
MEXICO
WHITE PINE
NYE
LINCOLN
CLARK
LAS VEGAS
WASHINGTON
KANE
MOHAVE
COCONINO
NAVAJO
APACHE
MC KINLEY
VALENCIA
CATRON
YAVAPAI
FLAGSTAFF
GILA
MARICOPA
PHOENIX
PINAL
GRAHAM
GREENLEE
GRANT
HIDALGO
YUMA
PIMA
TUCSON
SANTA CRUZ
COCHISE
SAN BERNARDINO
RIVERSIDE
IMPERIAL
LAKE MEAD
LAKE HAVASU
LAKE POWELL
COLORADO RIVER
LITTLE COLORADO RIVER
GILA RIVER
BASIN AND RANGE LOWLANDS
PLATEAU UPLANDS
CENTRAL HIGHLANDS
COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION
FLUORIDES IN GROUND WATER
30 0 30 60
SCALE IN MILES
OCTOBER 1969

GPO 856-793

Hardness--The Colorado River, from Lee Ferry to Imperial Dam, has mean hardness concentrations (as $CaCO_3$) ranging from about 300 to 375 mg/l. At Yuma this level doubles and the average hardness is 700 mg/l.

The hardness of Gila River waters will range from about 100 mg/l in the upper reaches to 900 mg/l at Gillespie Dam. Average concentrations of about 400 mg/l will be found at many points in the middle reaches above Ashurst-Hayden Dam. The waters of the Salt-Verde system are moderately hard; data for water years 1964-1966 indicate a mean hardness of 170 mg/l for both rivers.

Waters with hardness in the range of 60 to 120 mg/l would be the most suitable for general use, as some hardness is desirable to prevent undue corrosion. Waters containing from 120 to 180 mg/l may require softening for use. Treatment of waters with hardness concentrations exceeding 180 mg/l would most likely be advantageous for nearly all domestic and industrial uses and might be essential to some uses. Most ground water supplies are classified as hard water.

Chlorides--A recommended maximum concentration of 250 mg/l of chlorides in drinking water is set forth in the Public Health Service Drinking Water Standards. Lower concentrations of chlorides are usually recommended for most industrial uses, mainly because of the corrosiveness of chlorides to steel and aluminum. Chloride concentrations up to 1,500 mg/l have been reported as safe for livestock watering.

Chloride concentrations in the Lower Colorado River above Yuma are less than 250 mg/l. At Yuma they increase to an average of 600 mg/l. The Little Colorado River near its mouth frequently contains greater than 1,000 mg/l chlorides.

Maximum chloride levels in the Gila River periodically exceed 250 mg/l at sampling stations located above Ashurst-Hayden Dam. Much higher readings may be found in the Gila River near Bylas, Arizona. The 1967-68 study by the State of Arizona showed a mean chloride concentration of 400 mg/l with a high of 1,800 mg/l. Water impounded at Gillespie Dam had a mean chloride concentration of 450 mg/l with a maximum reading near 2,500 mg/l during water years 1964-66. Low levels of chloride are found in the Verde River, but the Salt River below Stewart Mountain Dam reflected a mean chloride level of 250 mg/l and a maximum of 340 mg/l during the 1964-66 period.

Sulfates--The Public Health Service Drinking Water Standards recommend a maximum sulfate concentration of 250 mg/l. Concentrations in the Colorado River generally exceed this amount. Many tributary streams are also high in sulfates. High sulfate readings are occasionally found in the upper waters of the Gila River. Average sulfate concentrations of 250 mg/l will be found in the Gila River from Kelvin, Arizona to Gillespie Dam. This limit is based primarily on the taste of water. Water may have a laxative effect on persons unaccustomed to the supply when concentrations reach about 600 mg/l if certain cations are present. High levels, above 600 mg/l, may be found in the Colorado River at Yuma. Concentrations exceeding 600 mg/l will also be occasionally found at points in the Gila River. The Salt and Verde Rivers are low in sulfates.

Concentrations of arsenic, chromium and lead in the Colorado River have on occasion exceeded the recommended or permissible criter for public water supplies delineated in the Report of the Technical Advisory Committee on Water Quality Criteria.(42)

Sediment

Rapid runoff from thunderstorms produces significant erosion in many parts of the Region. This, in turn, results in heavily sediment-laden streamflows. Because of the intermittent discharge pattern of many streams most of the sediment load is transported over only a few days of the year.

Criteria promulgated in the water-quality standards to limit quantities of suspended matter are based on turbidity measurements. Turbidity data are unavailable from which to evaluate the quality with respect to the standards. Furthermore, turbidity caused by sediment of natural origin is excepted from abatement by the water-quality standards of most of the Regional states.

The very large quantities of sediment transported in many streams present major problems in the development of water resources. Elaborate desilting works are required to remove sediment from impoundments and delivery systems. The reach of the Colorado River from Imperial Dam to Laguna Dam essentially serves as a depository for some 500,000 to 800,000 tons of sediment removed each year at the All American Canal Diversion. Substantial amounts of reservoir capacity are required for sediment storage in reservoirs throughout the Region.

Sediment entering the Lower Colorado River from the upper basin has been reduced to negligible amounts since construction of Glen Canyon Dam, although occasionally heavy sediment loads are carried in by the Paria River entering below

Glen Canyon Dam. Significant quantities of sediment reach the Colorado River from tributary streams in the northern part of the Lower Main Stem Subregion. Kanab Creek and the Muddy and Virgin Rivers are extremely turbid during periods of rapid runoff. Recorded sediment concentrations in Kanab Creek at Fredonia, Arizona have reached 700,000 ppm. Concentrations up to 500,000 ppm may often be found in this stream during periods of intense rainfall.

It has been reported that sediment loads carried in Kanab Creek and the Virgin River are at times so large as to require cessation of diversions until peak loads pass. Biological studies of the Virgin River showed serious degradation of the stream biota due to turbidity and the deposition of vast amounts of sediment along stream bottoms.(40) For the years 1963-1965 the Virgin River transported an average sediment load of over one million tons per year. A peak sediment concentration of about 180,000 ppm was observed in the Virgin River at Littlefield, Arizona in 1964. Aquatic life in the Colorado River upstream from the main body of Lake Mead is similarly affected by suspended and settled sediment.

The Little Colorado River contains vast quantities of sediment. Long-term records show an average annual sediment discharge of about 10 million tons at Cameron, Arizona. A maximum concentration of 200,000 ppm was recorded at Cameron in 1966. Heavy sediment loads are also carried in the headwaters of the Little Colorado. However, concentrations are less due to large stream flows.

Tributary streams contribute major quantities of sediment to the Gila River throughout its entire course. The San Carlos Reservoir in the upper part of the Gila River serves as a sediment control works. Yet, 60 miles downstream at Ashurst-Hayden Dam, mechanical removal is required for the large amounts of sediment added by the San Pedro River and other streams.

A maximum sediment concentration of 26,000 ppm was noted for the Gila River at Gila, New Mexico in 1962. Downstream near Solomon, Arizona, a maximum concentration of 92,000 ppm was observed in 1966. A concentration of 110,000 ppm was measured in the San Pedro River near Winkelman, Arizona in 1962. For the period 1963-65 an annual average of three million tons of sediment was discharged by the San Pedro River. During the period 1963-65 an average annual load of four million tons of sediment passed the Gila River gage at Kelvin, Arizona. At this point a maximum sediment concentration of 139,000 ppm was measured in 1961.

Bacteriological

For many years the coliform group of bacteria has been used as a bacterial indicator of pollution. The coliform group is made up of bacteria of diverse origin, including those found in the intestinal tract of humans and other warm-blooded animals as well as in soil and on vegetation. High coliform counts in water supplies are presumed to indicate the probable presence of pathogenic organisms if bacterial contamination from domestic sewage or animal wastes appears likely.

In recent years analytical procedures have been developed whereby coliform bacteria of fecal origin can be identified. Fecal coliform tests measure bacteria from both man and animal. An indication of whether pollution is caused by humans or animals is provided by the relationship between fecal coliforms and fecal streptococcus. The fecal coliform analysis provides a better indication of the possible occurrence of enteric pathogens than does the total coliform test due to the elimination of bacteria of non-fecal origin.

All the States of the Region have used fecal coliforms as a bacterial indicator of pollution in their water quality standards. Nevada and Utah have additionally specified total coliform criteria. Because the fecal coliform test is relatively new, very little historical fecal coliform data are available.

Total coliform data available from Water Pollution Surveillance System Stations on the Colorado River are shown in the following table:

Table 33 - BACTERIOLOGICAL QUALITY - COLORADO RIVER

Sampling Location	Total Coliform Density Count/100 ml 1/ Max.	Mean	Min.	Number of Samples	Period of Record
Page, Arizona	26,000	716	1	242	'60-'66
Boulder City, Nevada	28,000	326	1	397	'60-'67
Yuma, Arizona	8,600	470	1	182	'60-'65

1/ Membrane Filter Analyses

Heavy recreational development along the Colorado River in the Parker, Arizona area and the unauthorized recreational use of lands adjacent to the River below Parker, reportedly are presenting health hazards due to lack of adequate waste disposal facilities.(3)

Fecal coliform densities in Lake Mead along Boulder Beach increased from 2 to 700/100 ml during a period of heavy use over the Memorial Day Weekend in 1966.(46) This increase, which appeared to be directly attributable to the swimmers themselves, raised the fecal coliform counts considerably over the 100/100 ml upper limit promulgated by the State of Nevada for body contact recreation in waters of the Colorado River.

Total coliform densities above those permitted by the State of Utah Water Quality Standards can periodically be found in Kanab Creek and the Virgin River. This, along with the known discharge of untreated slaughter-house wastes to these waters, indicates probable pollution from pathogenic organisms.

Show Low Creek in the Little Colorado Subregion has been reported as being severly polluted due to inadequate sewage disposal systems to serve the influx of recreationists.(3) Extensive investigation is currently underway by the Arizona State Department of Health into pollution of Oak Creek in the Gila Subregion due to failures of septic tanks. Streams in the Mogollon Rim Country, another area of intensive recreational use, have also been polluted because of inadequate sanitary facilities.(3)

Although disinfection is required for municipal effluents septic tank discharges do not receive disinfection, therefore, the potential for bacteriological pollution increases in heavily populated areas served by septic tanks.

Studies conducted by the State of Arizona in 1967 and 1968 indicated that fecal coliform densities were not greater than 300 per 100 ml at any of the ten sampling locations on the Gila River system above Ashurst-Hayden Dam.(9) Mean densities ranged from 1 to 250 per 100 ml. Arizona standards for quality of the Gila River permit a mean fecal coliform density of 1000/100 ml.

Sufficient data are not available to analyze bacteriological quality of ground water. If present, bacterial pollution of ground water supplies would be expected to be confined to an area close to the source of pollution. Bacterial contamination is more likely to occur in areas of intensive use of septic tanks, such as heavily populated suburban areas, larger rural communities and areas of concentrated recreational development. The soils of the aquifer generally provide an effective barrier against bacterial pollution, but complete removal may not be effected over short distances. Viruses may travel considerable distance through the soil. Thus, the need for caution in locating shallow water-supply sources is apparent to preclude withdrawal of contaminated waters.

Nutrients

The over-enrichment of water by nutrients and the subsequent accelerated growth of aquatic plants are receiving national attention due to the major problems they are creating in many parts of the United States. In the Lower Colorado Region, no significant nutrient-associated problems have been identified except for Las Vegas Bay and Overton Arm of Lake Mead where algal growths have been excessive.(46)

Several mineral elements are needed to sustain aquatic life, but carbon, nitrogen and phosphorus are usually considered as the major fertilizing elements causing biological growths in water. Phosphorus is normally found in only limited quantities in natural water. Sufficient nitrogen is generally available in Regional waters to stimulate algal growths. Hard water in which the biocarbonate content is high contains a large amount of carbon dioxide which may be available for plant growth. In the presence of this nitrogen and carbon, phosphorus may cause excessive aquatic blooms when available in abundant quantities.

Significant populations of algae are present in some stream reaches, indicating that wastewaters entering the streams are rich in nutrients. Nutrient data collected at four Water Pollution Surveillance System Stations on the Colorado River are presented in Table 34. It is difficult to appraise such data because of the many factors contributing to excessive plant production. Investigation into nutrient problems in areas outside the Region has led to identification of limiting quantities of various forms of nitrogen and phosphorus, above which excessive fertility occurs. What may be critical in one instance, however, may not be under different conditions elsewhere.

Because the amount of phosphorus present in a form available for plant growth is constantly changing, the National Committee on Water Quality Criteria(45) recommends controlling the total amount of phosphorus present in streams. As a guideline the Committee recommends an upper limit of 0.1 mg/l for rivers with only 0.05 mg/l permitted where streams enter lakes or reservoirs. Data shown in Table 34 indicate that the phosphorus level in the streams is generally within the Committee limits.

Table 34 - PRESENT WATER QUALITY, NUTRIENTS
Colorado River

	Ammonia Nitrogen (mg/l as N)	Total Soluble Phosphate (mg/l)	Dissolved Phosphorus (Wet method mg/l as P)	Total Phosphorus (Wet method mg/l as P)
Near Page, Arizona				
Min.	0.00	0.00	0.01	0.01
Mean	0.21	0.10	0.01	0.03
Max.	0.90	7.60	0.02	0.24
No. of Samples	37	113	22	16
Period of Record	'62-'63	'61-'66	'65-'68	'65-'68
Near Boulder City, Nevada				
Min.	0.00	0.00	0.01	0.01
Mean	0.00	0.00	0.01	0.01
Max.	0.00	0.00	0.10	0.03
No. of Samples	59	50	32	23
Period of Record	'60-'62	'61-'64	'65-'68	'66-'68
At Parker Dam				
Min.	-	0.00	0.01	0.01
Mean	-	0.01	0.03	0.01
Max.	-	0.30	0.50	0.03
No of Samples	-	123	24	21
Period of Record	-	'60-'65	'66-'68	'66-'68
At Yuma, Arizona				
Min.	0.00	0.00	0.01	0.01
Mean	0.80	0.01	0.01	0.02
Max.	1.40	0.50	0.01	0.03
No. of Samples	4	117	5	6
Period of Record	'62-'65	'61-'65	'65-'68	'65-'68

Quiescent reservoir waters are more susceptible to excessive plant growths than are rapidly flowing streams. Excessive growths of aquatic plants are present in Las Vegas Bay resulting from inputs of large amounts of nutrients into the Lake. The nutrients are derived primarily from municipal and industrial effluents from metropolitan Las Vegas that are carried into the Lake by Las Vegas Wash. During April 1966 about 2,000 pounds of soluble phosphorus entered Lake Mead from tributary flows. Sixty-two percent of the soluble phosphorus by weight and 98 percent of the flow came from the Colorado River. The Muddy and Virgin Rivers combined contributed 3 percent of the phosphorus and 1.8 percent of the flow. Las Vegas Wash contributed only 0.2 percent of the flow yet added 35 percent of the phosphorus. Concentrations of soluble phosphorus ranged from a low of 0.015 mg/l in the Colorado River at the upper end of Lake Mead to a high of 4.25 mg/l in Las Vegas Wash.[40]

Total phosphorus at the mouth of Las Vegas Wash measured 7.0 mg/l -- 140 times greater than the 0.05 mg/l criterion for streams entering reservoirs. This along with other factors, caused an algal concentration of 39,300/ml at the surface near the mouth of the wash. Algal concentrations of 92,000/ml have been observed in Lake Mead at a water supply intake near Saddle Island. Algal concentrations decrease with distance from the wash and conditions within the main body of the lake are acceptable. Floating mats of algae that have drifted from the vicinity of the wash may be observed in the lake at times.

In the lower reaches of the Lower Main Stem Subregion, stimulation of aquatic-plant growths has been associated with fertilization by nutrients discharged in irrigation-return flows.[40] No interferences with beneficial uses were reported. A small increase in nutrient levels in the Colorado River has been attributed to waste discharged from recreational activities in the Parker, Arizona area.

Municipal wastes from Yuma have effected a four-fold increase in the amount of total phosphorus found in the Colorado River in that area. No nutrient information is available for either the Little Colorado or Gila Subregions.

Radiological

Before the completion of Upper Colorado River storage reservoirs, sediments which had become contaminated by uranium milling waste discharges in the Upper Colorado Region were eventually deposited in the Lower Colorado Region in Lake Mead. The effects of these radioactive deposits is noted by the increased Ra-226 concentrations in Lake Mead as compared to those observed upstream at Page, Arizona as shown in the following table.

Table 35 - RADIUM-226 IN WATERS OF THE COLORADO RIVER

Sampling Location	Mean Annual Concentrations (Picograms per liter) 1963	1964	1965	1966	1967
Page, Arizona	0.25	0.25	0.17	0.15	0.14
Lake Mead	0.33	0.31	0.41	0.41	0.32
Lake Havasu	0.35	0.36	0.36	0.39	0.34
U.S.-Mexico Border	0.17	0.18	0.16	0.16	0.17

Although substantial amounts of radioactive sediments are stored in Lake Mead, they are not considered to represent a major source of contamination. The continuing presence of radium-226 in the water, even though radioactive inputs have diminished, is apparently due to erosion, mixing and leaching of radioactive sediments caused partly by fluctuations in water levels. Water-quality measurements in Lake Havasu show that radium-226 levels remain about the same as in Lake Mead whereas farther downstream at the International border the concentrations are about one-half of the Lake Mead and Lake Havasu readings.

Ra-226 values presented in Table 35, are well within the limits delineated in the State of Arizona water quality standards.

An assessment of radiological pollution should also consider strontium-90, a radionuclide associated with atmospheric fallout and like radium-226 damaging to bone cells. Strontium-90 data are presented in the following tabulation.

Table 36 - STRONTIUM-90 IN WATERS OF THE COLORADO RIVER

Sampling Location	Mean Annual Concentrations (Picocuries per liter) 1963	1964	1965	1966	1967
Page, Arizona	2.85	5.40	2.30	3.15	3.80
Lake Mead	1.15	1.40	2.00	---	3.00
Lake Havasu	1.00	2.05	1.50	3.30	4.50
U.S.-Mexico Border	1.35	1.18	1.40	2.50	2.30

The concentrations of Sr-90 are well below the maximum of 10 picocuries per liter recommended by the Public Health Service for drinking water supplies.

Effects of Ra-226 and Sr-90 are synergistic. Total amounts of Ra-226 and Sr-90 are satisfactory with respect to their combined limits.

In early 1964, surface and ground waters in the vicinity of the Tuba City uranium mill in the Little Colorado Subregion were sampled to determine if pollution was occurring due to seepage from wastewater-disposal ponds. None was indicated and the maximum radium-226 concentration found was 0.1 picogram per liter. Naturally high levels of radioactivity may be found in ground water in some areas as evidenced by the radioactivity in spring discharges cited in the Geologic Sources of Pollution section.

Dissolved Oxygen

Dissolved oxygen is necessary to provide an aquatic environment capable of supporting fish and other aquatic life. In the absence of adequate dissolved oxygen, the capacity of a stream to assimilate residual organic wastes is significantly reduced. Under such conditions, unpleasant sights and odors may develop. The dissolved oxygen content of water is affected by many factors including the velocity and quantity of flow, depth, temperature, deoxygenating effects of pollutants, and photosyntheses of aquatic plants.

Significant diurnal variations in dissolved oxygen may occur due to the photosynthetic activity of algae and other water plants. In the presence of abundant plant growths, the oxygen given off during daylight hours may cause supersaturated dissolved oxygen levels. Minimum concentrations are found during the night hours or other periods of reduced sunlight when oxygen is consumed by the plants.

In streams having wide diurnal variations, the low night-time dissolved oxygen concentrations may be critical. Regardless of the day-time highs, a short-duration minimum level may adversely affect fish. Diurnal dissolved oxygen data are not available, but super-saturated daylight conditions are periodically observed.

Dissolved-oxygen data available from water pollution surveillance system stations on the main stem of the Colorado River are tabulated below.

Table 37 - DISSOLVED OXYGEN CONCENTRATIONS
(mg/l)

Sampling Location	Max.	Mean	Min.	Number of Samples	Period of Record
Page, Arizona	13.5	9.6	5.0	124	62-66
Boulder City, Nevada	12.4	7.7	4.1	306	60-67
Parker Dam	12.9	10.2	5.5	114	63-67
Yuma, Arizona	17.4	9.5	2.7	131	62-66

The States of Arizona and Nevada set a minimum dissolved oxygen content of 6.0 mg/l for the Colorado River provided that, in the case of Arizona, the reach in question is a fish and wildlife habitat.

Water-quality monitoring during 1968 indicated generally satisfactory dissolved-oxygen conditions in major tributary streams of the Lower Main Stem Subregion. Mean annual concentrations ranged from 6.8 mg/l in Las Vegas Wash at the USGS flow-measurement gage near Henderson, Nevada, to a high of 9.0 mg/l further downstream in Las Vegas Wash near its confluence with Lake Mead. Mean annual dissolved-oxygen concentrations of about 8.5 mg/l were recorded for Kanab Creek below Kanab, Utah, and for the Virgin River below St. George, Utah, and at Riverside, Arizona. A minimum level of 3.6 mg/l was observed in Las Vegas Wash near Henderson. Minimum readings at other stations were at least 6.2 mg/l. Maximum values ranged to 12.4 mg/l.

Limited sampling in the Gila River above Ashurst-Hayden Dam indicated a range in mean dissolved-oxygen concentrations from 8.1 mg/l to 10.4 mg/l during 1967-1968. The Arizona Water Quality Standards delineate a minimum criterion of 6.0 mg/l of dissolved oxygen for fish and wildlife propagation in the Gila River. Minimum levels of 5.5, 6.5, and 6.6 mg/l were noted near Thatcher, Arizona, at the New Mexico-Arizona stateline, and near Guthrie, Arizona, respectively. High readings ranged to 14.1 mg/l.

No dissolved-oxygen data are available for streams in the Little Colorado Subregion.

Pesticides

Limited monitoring for residual pesticides in streams has been conducted at the four Water Pollution Surveillance System Stations located on the Colorado River. The pesticides DDD, DDE, DDT, Dieldrin and Endrin have been detected at these stations. No data for pesticides in other streams are available. Likewise, no pesticides data are available for groundwater supplies.

Data are not adequate to provide comprehensive evaluations of the effects of pesticides on the quality of the waters of the Region.

Several fish and bird mortalities attributed to residual pesticides have occurred in recent years downstream of or in irrigation drains in Yuma County in the Lower Main Stem Subregion. The largest fish kill occurred in August 1966 in the Yuma Project Main Drain. About 55,000 fish were killed. The Arizona State Health Department reported the pesticide Parathion as the cause. During September 1967, 190 dead game-birds were found in the Cibola, Arizona area. Their deaths, according to the U.S. Fish and Wildlife Service, were caused by the pesticide Azodrin.

Temperature

Water temperatures reach their highest levels during the months of June, July, August and September. During this period stream temperatures range from highs in the 90's to lows in the 50's. Lowest temperatures during the summer are found downstream of cold-water discharges from reservoirs. Stream temperatures at selected points are presented in Table 38. The data indicates that temperatures are generally satisfactory with respect to the criteria set by the states for designated stream uses.

Variations in stream temperatures result from climatic conditions, quantity of flow, municipal and industrial wastewater discharges, irrigation return flows, storage in impoundments, and flow from thermal springs. The effect of diversions and return flows is more noticeable in the summer months because of higher temperatures and the increased demand at that time for domestic, irrigation, and industrial water.

Table 38 - SUMMER STREAM TEMPERATURES
(Degrees Fahrenheit)
Lower Colorado Region

	June			July			August			September		
	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.
Colorado River at Lee Ferry, Arizona	62	57	52	70	64	58	69	63	48	76	70	58
Little Colorado River at Cameron, Arizona	--	--	--	85	81	65	88	80	60	85	73	58
Colorado River at Grand Canyon, Arizona	75	64	57	79	71	64	78	71	70	74	70	63
Virgin River at Littlefield, Arizona	87	77	64	92	81	71	87	81	67	83	75	63
Colorado River below Parker Dam	76	73	70	79	77	73	81	79	75	78	76	71
Colorado River below Cibola Valley, Arizona	83	77	70	86	82	78	87	83	76	83	78	71
Gila River near Gila, New Mexico	84	73	61	85	78	67	87	78	70	82	72	58
San Pedro River at Charleston, Arizona	87	67	55	82	72	65	85	73	61	82	66	49
Gila River at Kelvin, Arizona	89	79	66	92	81	65	91	80	60	88	75	51
Salt River below Stewart Mountain Dam	68	61	57	67	64	62	70	67	62	71	69	67
Verde River below Bartlett Dam	60	59	58	78	67	58	80	72	63	80	79	77
Gila River below Gillespie Dam	82	79	76	88	85	78	98	87	78	88	79	65

SOURCE: USGS Water Quality Records, Water Years 1964-1966

FUTURE DEMANDS

Projected Waste Loads

Municipal Wastes

The population of the Region is projected to increase nearly 400 percent in the 55-year study period, from 1965 to 2020. The largest increase in population is projected for the Gila and Lower Main Stem Subregions where most of the growth will occur in the Phoenix and Tucson, Arizona and Las Vegas, Nevada areas, respectively.

Table 39 - PROJECTED POPULATION OF THE LOWER COLORADO REGION 1/

	1965	1980	2000	2020
Lower Main Stem	345,200	556,200	1,023,200	1,756,000
Little Colorado	125,000	180,000	219,600	261,700
Gila	1,406,800	1,907,900	3,020,400	4,621,500
Lower Colorado Region	1,877,000	2,644,100	4,263,200	6,639,200

1/ Source: Economic Base and Projections Appendix. (Based on Economic Subregions)

The following tabulation depicts the estimated urban-rural distribution of the future population. The change in the urban-rural character was estimated from published demographic projections.[14] The division of the rural population into rural non-farm and rural farm classifications was assumed to remain essentially unchanged from present conditions.

Table 40 - ESTIMATED DISTRIBUTION OF FUTURE POPULATION
(Percent of Total Population)

	1965	1980	2000	2020
	--Urban--			
Lower Main Stem Subregion	79	88	92	96
Little Colorado Subregion	36	45	50	56
Gila Subregion	84	92	94	96
Lower Colorado Region	80	88	91	94
	--Rural Non-Farm--			
Lower Main Stem Subregion	18	10	7	3
Little Colorado Subregion	52	44	40	35
Gila Subregion	14	7	5	3
Lower Colorado Region	17	10	7	4
	--Rural Farm--			
Lower Main Stem Subregion	3	2	1	1
Little Colorado Subregion	12	11	10	9
Gila Subregion	2	1	1	1
Lower Colorado Region	3	2	2	2

Increased municipal populations will result in increased discharges of domestic and service-industry wastes to public sewers. The increase in municipal waste production was estimated to correspond directly to the increase in municipal population.

Table 41 - ESTIMATED UNTREATED MUNICIPAL WASTES
(tons/year)

	1965	1980	2000	2020
	--BOD--			
Lower Main Stem Subregion	10,200	17,400	33,200	57,000
Little Colorado Subregion	2,600	4,000	5,300	6,300
Gila Subregion	42,500	60,200	97,800	149,600
Lower Colorado Region	55,300	81,600	136,300	212,900
	--TDS--			
Lower Main Stem Subregion	23,600	40,400	76,800	131,900
Little Colorado Subregion	6,400	10,000	13,100	15,600
Gila Subregion	100,000	141,700	230,100	352,100
Lower Colorado Region	130,000	192,100	320,000	499,600
	--P--			
Lower Main Stem Subregion	425	730	1,380	2,370
Little Colorado Subregion	105	160	210	250
Gila Subregion	2,020	2,860	4,650	7,110
Lower Colorado Region	2,550	3,750	6,240	9,730

Rural-Domestic Wastes

The rural-domestic population is estimated to decrease slightly between 1965 and 2000, then increase at a slow rate through the remainder of the study period to a 2020 level about one-tenth higher than the 1965 population. The pattern within each subregion differs somewhat as indicated by the waste loads in the table presented on the following page.

Table 42 - ESTIMATED UNTREATED RURAL-DOMESTIC WASTES
(tons/year)

	1965	1980	2000	2020
	--BOD--			
Lower Main Stem Subregion	1,300	1,100	1,100	1,900
Little Colorado Subregion	1,500	1,800	1,900	2,300
Gila Subregion	4,000	2,900	2,100	3,300
Lower Colorado Region	6,800	5,800	5,100	7,500
	--TDS--			
Lower Main Stem Subregion	3,000	2,600	2,600	4,500
Little Colorado Subregion	3,400	4,200	4,300	5,200
Gila Subregion	9,200	6,600	5,000	7,700
Lower Colorado Region	15,600	13,400	11,900	17,400
	--P--			
Lower Main Stem Subregion	70	60	60	100
Little Colorado Subregion	80	100	100	120
Gila Subregion	180	130	100	150
Lower Colorado Region	330	290	260	370

Industrial Wastes

Manufacturing--The total value added from manufacturing is projected to increase from the 1965 level of $741 million to $13.3 billion in 2020. A similar growth is projected for manufacturing employment which is projected to increase from 90,900 in 1965 to 459,500 in 2020. The majority of the manufacturing output continues to be produced by industries located in the Gila Subregion.

Projected increases in manufacturing output should not result in direct increases in the amount of gross wastes produced as improvements in manufacturing processes are expected to decrease the amount of waste generated per unit of product output. More efficient use of raw materials, including water, better waste reclamation practices, and greater water reuse, are factors affecting the quantity of wastes produced. It is estimated that, as an average, unit output of untreated wastes in 1980 will be about 90 percent of the 1965 loading. Additional 5 percent decreases in the amount of wastes produced per production unit are expected during each of the last two timeframes.

Table 43 - ESTIMATED UNTREATED MANUFACTURING WASTES
(tons/year)

	1965	1980	2000	2020
	--BOD--			
Lower Main Stem Subregion	4,700	7,700	13,700	19,600
Little Colorado Subregion	700	800	1,000	1,100
Gila Subregion	25,500	39,200	54,000	71,500
Lower Colorado Region	30,900	47,700	68,700	92,200
	--TDS--			
Lower Main Stem Subregion	8,000	12,900	23,100	33,200
Little Colorado Subregion	1,300	1,400	1,800	2,000
Gila Subregion	78,000	120,200	165,500	219,200
Lower Colorado Region	87,300	134,500	190,400	254,400

The total present and projected raw waste production from municipalities and manufacturing installations is shown in Figure 4.

Electric Power Production--According to data presented in the Electric Power Appendix, a 28-fold increase in plant capacity is projected in the Lower Colorado Region for the 55-year period 1965 through 2020. Most of this planned production is for use within the Region.

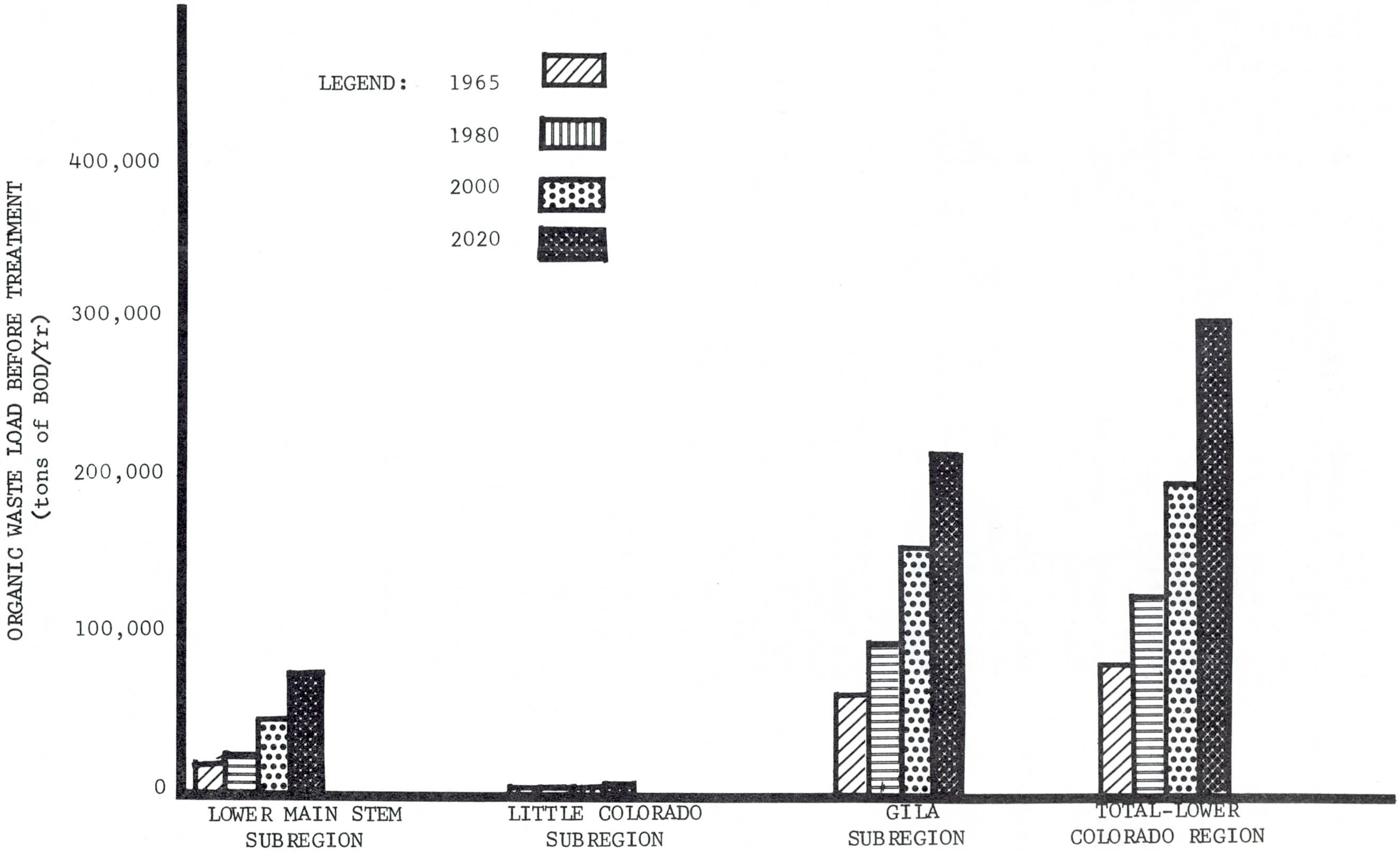


Figure 4--Present and Projected Waste Production from Municipal and Industrial Sources

Nuclear-fueled thermal power generating will provide an estimated 60 percent of the electric power in the year 2020, while fossil-fueled thermal power will provide an estimated 27 percent. The remaining 13 percent will be produced by hydroelectric works. Construction trends indicate that large-scale thermal power installations will be built. Increased size has been a major factor for increased thermal efficiency, however, present generating methods appear to be approaching the limits of efficiency possible under current technology.(43) Waste heat increases can be expected to more closely parallel power production increases in the foreseeable future.

The most efficient fossil-fueled plant presently operates at about 40 percent efficiency. With boiler, stack, and miscellaneous losses totaling about 15 percent of the thermal input for coal-fired plants, the waste heat to cooling systems amounts to about 45 percent of the thermal input.

The efficiency of nuclear plants now being built or planned to 1975 will not exceed 33 percent. The waste heat to cooling water systems for nuclear-fueled plants is about 60 percent of the thermal input, assuming boiler, stack and miscellaneous losses of 5 percent. Generally it is estimated that with current technology, heat wasted for cooling from nuclear plants may range up to 50 percent greater than from a comparable fossil-fueled steam-electric plant.

A summary of the estimated total Lower Colorado Region waste heat to cooling water systems from the thermal power industry is shown in Table 44.

Table 44 - WASTE HEAT TO ELECTRIC POWER COOLING WATER SYSTEMS 1/
(Billion BTU/Hr)

	1965	1980	2000	2020
Lower Main Stem Subregion	2.1	9.1	21.8	48.5
Little Colorado Subregion	0.6	0.5	0	0
Gila Subregion	7.6	7.6	47.2	204.4
Lower Colorado Region	10.3	17.2	69.0	252.9

1/ Source: 1965 Estimated; 1980-2020 from Electric Power Appendix.

If evaporative or non-evaporative cooling methods are employed as planned at all future thermal generating stations, thermal pollution from this source would be almost nonexistent.

Mining--Continued growth is projected for the mining industry to 1980, 2000 and 2020, although production of some of the minerals presently mined will decline.

According to the Mineral Resources Appendix, "There is no objective reason to believe that any of the important mineral commodities customarily produced in the Lower Colorado Region could be depleted physically through 2020. In contrast, there are numerous factors -- primarily of an ecologic, economic, or technologic nature -- that appear virtually certain to modify the traditional approach to mineral resources development."

Copper comprises about 80 percent of the total annual mineral production and should maintain its position through 2020.

Annual uranium output is expected to be essentially unchanged through 2020. Although the change from fossil-fueled to nuclear-fueled electric power plants is still anticipated throughout most of the nation, the transition may require considerably more time than was generally expected, in view of the many delays currently being encountered in the construction of nuclear powerplants.

Coal production from the Black Mesa area of northwest Arizona should increase significantly to meet the needs of the projected coal-fired electric utilities. Discovery of oil in the Four Corners area will increase the petroleum output without interruptions through 2000 and then decline through 2020.

Lead-zinc, the fourth leading mineral commodity produced in 1965, will drop to about eighth place in 2020. Sand and gravel production will continue to grow through 2020, along with cement, lime, stone, gypsum and pumice.

Water use by the mining industry resulted in a depletion of 60,000 acre-feet in 1965. Water depletions are estimated to increase up to 65 percent by 1980 and up to 275 percent by 2020.

Agriculture

Irrigation Return Flows--Under the Modified OBE-ERS projections, it has been estimated that in order to supply a future need for food and fiber in the Region, 1,316,000 acres of land will have to be irrigated in the year 1980; 1,398,000 acres in year 2000; and 1,429,000 acres in year 2020. 1,160,000 acres were irrigated in 1965.

Table 45 - FUTURE IRRIGATED ACREAGE 1/

	1965	1980	2000	2020
Lower Main Stem Subregion	237,000	297,000	309,000	336,000
Little Colorado Subregion	28,000	34,000	36,000	35,000
Gila Subregion	895,000	985,000	1,053,000	1,058,000
Lower Colorado Region	1,160,000	1,316,000	1,398,000	1,429,000

1/ Source: Irrigation and Drainage Appendix.

Irrigation of additional lands will cause an increase in the amount of dissolved solids flowing in the downstream reaches of the Colorado River and some of its tributaries, resulting mainly from the salt concentrating effect of stream depletion. Locations of new lands to be irrigated were not identified, however, the Colorado River Indian Reservation has water rights sufficient to irrigate an additional 67,500 acres of land. Also, the displacement of irrigated lands in the Salt River Valley by urbanization will result in new lands being placed under irrigation, probably in an area west of Phoenix.

The total crop consumptive use of water will increase from 3,938,000 acre-feet in 1965 to 4,812,000 acre-feet by the year 2020. This represents an increase of 12 percent over the existing theoretical crop consumptive use. The total Regional water withdrawal requirement decreases from 8,903,000 acre-feet in 1965 to 8,260,000 acre-feet in 2020--a decrease of 7 percent in the 1965-2020 period.

Reasons for the expected decrease are higher irrigation efficiencies, lined distribution systems, and improved farm practices. Little change in the cropping pattern is expected.

Dissolved solids pickup from new lands was not calculated. Development of the Colorado River Indian Reservation's 67,500 acres of new lands would probably result in considerable additional salt load being discharged to the Colorado River. Likewise, the initial leaching of new lands in other locations will probably increase the salt load of irrigation return flows.

Future use and detrimental effects from pesticides, herbicides and other biocides cannot be determined at this time. It is anticipated that scientific studies in characteristics and capabilities of pesticides and regulations restricting use will keep detrimental effects to a minimum.

Future nutrient loads from agricultural fertilizers could not be quantified because of the sparse information describing present and future use of agricultural chemicals. It is assumed that fertilizer use will increase as increased fertilizer applications were a factor in determining the higher crop yields projected by the Economics Workgroup.

Animal Waste--The projected 2020 waste production from confined livestock and poultry is estimated to increase nearly five-fold over the base year. This will result in a considerable increase in the amounts of nitrogen and phosphorus produced, along with an increase in biochemical oxygen demand. Pollution problems are not expected to be much more severe than at present provided that pollution abatement measures are taken.

Table 46 - ESTIMATED WASTE PRODUCTION FROM LIVESTOCK AND POULTRY IN CONFINEMENT
(tons/year)

	1965	1980	2000	2020
	--BOD--			
Lower Main Stem Subregion	18,200	41,200	67,500	95,900
Little Colorado Subregion	400	300	400	500
Gila Subregion	130,500	361,500	473,600	581,800
Lower Colorado Region	149,100	403,000	541,500	678,200
	--N--			
Lower Main Stem Subregion	6,200	14,600	22,300	32,000
Little Colorado Subregion	50	30	40	40
Gila Subregion	42,300	120,600	158,600	195,000
Lower Colorado Region	48,550	135,230	180,940	227,040
	--P--			
Lower Main Stem Subregion	1,900	4,500	6,800	9,700
Little Colorado Subregion	30	20	30	30
Gila Subregion	13,000	36,600	48,000	59,000
Lower Colorado Region	14,930	41,120	54,830	68,730

With the improvement of the road transportation network there has been little need for cattle feedlots to remain close to population centers in order to take advantage of highways and railroads. This change is seen in the gradual shift of feedlots to an area in the Casa Grande Valley between Phoenix and Tucson. This area is served by all-weather roads as well as a railroad and is in an area where feed grains are grown. This appears to be a major area of future expansion of cattle feedlots.

Hog feedlots will probably continue to be located away from population centers because of their offensive odors.

Poultry raches, on the other hand, seem to be more compatible with urbanization. Many poultry ranches have been established on the fringes of population centers. The large ranches, however, are usually located in the country. The trend has been toward the larger ranch so it seems likely most poultry ranches will be in the country.

Recreation

Total outdoor recreation demand will increase six-fold during the 1965-2020 period and water-based recreation will increase at about the same rate.

Table 47 - PROJECTED RECREATION DEMAND 1/
(Recreation Days in Thousands)

	1965	1980	2000	2020
--Total Recreation--				
Lower Main Stem Subregion	41,646	92,431	193,600	313,081
Little Colorado Subregion	19,381	35,905	63,172	101,091
Gila Subregion	77,158	139,271	283,006	503,407
Lower Colorado Region	138,185	267,607	539,778	917,579
--Water-Based Recreation--				
Lower Main Stem Subregion	11,432	25,372	53,143	85,941
Little Colorado Subregion	5,320	9,856	17,341	27,749
Gila Subregion	21,180	38,230	77,685	138,185
Lower Colorado Region	37,932	73,458	148,169	251,875

1/ Source: Recreation Appendix.

Most of the recreation expansion will occur on public lands presently under jurisdiction of the U.S. Forest Service, National Park Service, Bureau of Land Management and Fish and Wildlife Service.

The Colorado River, within the Lower Main Stem Subregion, provided about 75 percent of the surface acreage of water available in the Region for recreation use in 1965. This presents a problem when comparing the future water-based recreation demand of the Gila Subregion which has the greatest demand with the Lower Main Stem which has most of the supply. A part of the demand in the Phoenix area may be met by facilities of the Central Arizona Project. Future water-based recreation demand in the Tucson area of the Gila Subregion will be partly met by the proposed aquatic park complex to be developed through the reclamation of municipal wastewaters.

Increased use will impose additional demands on the recreational resources of the area, including quality of water. As pointed out under the present status of recreation, the total amount of waste generated annually in the course of recreation provides little meaning as an indicator of the potential for water pollution. More important is the concentration of recreation pursuits in both time and place.

WATER QUALITY MANAGEMENT NEEDS AND MEANS OF MEETING THE NEEDS

By recognizing the present water quality problems and developing comprehensive plans at this time to combat future demands on water resources, effective management of water quality and pollution control problems can be accomplished. This report, by describing the needs and possible programs for maintaining the quality of the aquatic environment, represents the first step in the development of a Region-wide comprehensive program for water quality management.

All agencies and organizations involved in making decisions about land and water resource use must continue to strengthen their programs for water quality management. This extends beyond those agencies specifically charged with water pollution control--although the primary responsibility rests with them--to all governmental authorities having lesser interests or control over activities that affect water quality. Development of complementary and mutually supporting programs by local, state, and federal agencies is needed.

In general, increased staffing of agencies is needed to adequately carry out the necessary programs. Federal grants are available to assist state and interstate water quality management programs.

The Water Quality Standards established by the states in accordance with the Water Quality Act of 1965 represent a major step in pollution control. The standards and their implementation plans are, in themselves, plans for controlling pollution. Expansion of the standards to include intrastate as well as interstate streams is needed where this has not been done. Also, the water quality criteria should be expanded to cover additional parameters in order to provide a more complete measure of water quality.

The difficulty of maintaining or restoring water quality is continually increasing because of the growing quantity of effluents that are entering streams and the increasing depletions. Increases in pollution may result not only from population growth and industrial expansion but also from intensification of water resources development. Although many situations can be met with existing knowledge, there is a continuing need for technological improvement in waste removal, treatment methods, and erosion control measures. In addition, there are situations for which the feasibility of solutions have not yet been determined. The control of salinity, for example, will require research and demonstration efforts to develop effective control measures.

Data describing wastewater and stream quality conditions are limited. Expansion of present surveillance programs is needed in order to provide better stream coverage and to measure additional water quality parameters. A thorough knowledge of water quality conditions, waste loadings, and streamflow characteristics will permit the utilization of computerized mathematical modeling as a tool for better water quality management.

The greatest challenges to water quality management may not be those of a technical nature but could be the constraints imposed by existing legal and institutional arrangements. The environment of the Colorado River Basin has historically dictated the establishment of legal systems and institutional arrangements to manage a scarce water resource. There is an increasing awareness in the Colorado River Basin that the problems of water quantity cannot be divorced from the problems of water quality. The search for solutions to the water quality problems defined herein must necessarily extend to an examination of existing legal systems and institutional arrangements to determine their efficacy in implementing any proposed plan for the management of water quantity and quality.

The objective of these programs is to outline means to help maintain the quality of water at levels suitable to meet the criteria of the state-federal water quality standards. In the absence of water-quality criteria for specific water uses or water-borne materials in the standards, the programs are based on recommendations for allowable amounts of potential pollutants that are delineated in several reference publications. Among these are the "Water Quality Criteria Report of the National Technical Advisory Committee to the Secretary of the Interior,"[45] "Water Quality Criteria," by McKee and Wolf,[15] and Public Health Service Drinking Water Standards."[27]

From an evaluation of the present conditions of water quality and pollution control and the demands expected from future development, the following principal water quality management needs have been identified:

1. Improve salinity conditions.
2. Manage streamflows for water-quality improvement.
3. Manage ground-water supplies for quality.
4. Improve wastewater treatment.
5. Control thermal discharges.
6. Improve watershed management practices.
7. Reduce pollution from agricultural operations.
8. Control accidental spills of hazardous materials.

Salinity Improvement Program

Early in the process of establishing water quality standards the lack of information on salinity management and control became readily apparent. In 1966, representatives of all seven Colorado River Basin states met to consider a common framework of guidelines so that the water quality standards for the Colorado River System, to be set separately by the seven states of the basin, would be mutually compatible. The conferees agreed that the water quality standards should state the criteria for salinity in qualitative terms only, pending the acquisition of more data and knowledge.

On January 30, 1968 Secretary of the Interior Stewart Udall testified at hearings of the House Interior and Insular Affairs Subcommittee on Irrigation and Reclamation regarding water quality standards. At that time, he presented a statement that contained the following sentence:

> "Before discussing this problem further, I would like to state that salinity standards will not be established (for the Colorado River) until we have sufficient information to assure that such standards will be equitable, workable, and enforceable."

The same position was reiterated by Assistant Secretary of the Interior Max Edwards in a letter dated February 12, 1968. At this time he also stated that the Department of the Interior intends to pursue active programs to lay the foundation for setting numerical standards at some future time.

There is disagreement among the seven Colorado River Basin states to the need for numerical salinity criteria.

During the course of the Framework Study, and in order that salinity improvement measures to improve water quality in the Lower Colorado Region might be included in the Upper Colorado Region Appendixes, the states of the Colorado River System agreed to the following:

"The following principles and conditions concerning a basinwide salinity improvement program shall be included in the Analytical Summary Report and the appropriate Region Appendixes.

1. The framework study is a logical vehicle for establishing recommendations for a Colorado River Basin salinity improvement study.

2. By the inclusion of a basinwide salinity improvement program in the framework plan, pilot projects and further detailed studies to determine the desirability and feasibility of a basinwide salinity improvement program may be expedited.

3. Any depletion of water resulting from programs included in a basinwide salinity improvement program shall be prorated to the beneficiaries in accordance with the benefits.

4. Cost estimates for that portion of a basinwide salinity improvement program included in the Upper Region may be developed in the Upper Region Water Quality Appendix but none of the costs associated with the program will be included in the tabulation of Upper Region costs as they are not necessary for Upper Region development. Such costs will be included in the Analytical Summary Report."

As a result of further discussions among state and federal representatives in both the Upper and Lower Colorado Regions it was agreed that the salinity improvement programs outlined in the Upper and Lower Colorado Framework Study documents would be part of a basinwide approach to salinity management. The program outlined in this appendix, therefore, is for that portion of a basinwide program that could be located in the Lower Colorado Region. Further discussions of a basinwide program including suggested measures for financing and implementation are presented in the Pacific Southwest Analytical Summary Report.

There are salinity improvement measures that could be undertaken in the Lower Colorado Region with considerable success, however, a program in both the Upper and Lower Colorado Regions appears to be the most reasonable approach to salinity management in the lower Colorado River. Although these two geographic areas are separated for purposes of this study, the salinity of water entering the Lower Colorado Region is dependent upon the activities and programs in the Upper Colorado Region. Accordingly, development of a salinity improvement program for the Lower Colorado Region is considered to be a function of two related and important considerations. One factor is the program itself for minimizing the salt load and associated salinity concentrations.

The program, as outlined in this section, is based upon reconnaissance studies as well as recommendations of the Water Quality Office of the Environmental Protection Agency.[49] and required some broad and simplified assumptions. The other factor being the programs that may be developed in the Upper Colorado Region.

The salinity improvement program suggested in the Upper Colorado Region Water Quality, Pollution Control and Health Factors Appendix would remove an estimated 2.2 million tons of salt annually by 2020 and maintain a salinity level of about 600 mg/l at Lee Ferry throughout the study period.

The program for the Lower Colorado Region suggests the impoundment and evaporation of flows from LaVerkin Springs and desalination of municipal effluents from Las Vegas Wash. LaVerkin Springs, located on the Virgin River in southern Utah, would be collected and piped through a 9-mile gravity aqueduct to an evaporation pond, removing more than 100,000 tons of salt annually or about one percent of the annual salt load at Lake Mead. Completion by 1980 is suggested for this project. The suggested wastewater treatment program for metropolitan Las Vegas, Nevada includes a desalination plant to reclaim wastewater for reuse. The desalting unit would reduce the salt discharge to Lake Mead by about 100,000 tons annually by 2000.

A suggested alternative in the salinity improvement program is the control of Blue Spring and the other mineralized springs located near the mouth of the Little Colorado River. This program element could be carried out in the 1980-2000 period to provide additional power, improved water supply and salt load reduction. Project features would include a three-stage pumped storage hydro-electric project near the mouth of the Little Colorado River; an 80-mile aqueduct; a second pumped storage hydro-electric project located southwest of Flagstaff, Arizona to offset pumping costs; and a large-scale nuclear power plant, including a 200 mgd desalination works and brine disposal facilities. Demineralized water could be sold to municipal and industrial water users in Central Arizona by discharging the water to the Verde River system. The project could capitalize upon the expanding demand for electric power in the southwest and the water needs of the Central Arizona area. This alternative would prevent the addition to Lake Mead of an annual salt load of about 500,000 tons. The most serious potential limitation of constructing this large project would be the relationship that it has to the Central Arizona Project with regard to Arizona's allotment of Colorado River water. Other factors are the need to sell the entire project concept to a major power company or consortium and the potentially serious and severe impacts on the environment.

The salinity improvement program, thus far, has dealt only with control of salt loading. Water depletion requirements are projected to increase from 1.2 million acre-feet per year to about 2.2 million acre-feet per year in the Lower Main Stem Subregion between 1965 and 2020. A significant increase in salinity concentrations results from the concentrating effects of depletions for irrigation and, in the Lower Main Stem Subregion, especially from the projected development of an additional 89,000 acres of irrigated lands. These new lands may produce high salt loads during initial leaching.

The concentrating effect of reservoir evaporation and other losses are significant. Evaporation losses from reservoirs on the lower Colorado River, from Lake Mead to Imperial Dam, exceed 1.2 million acre-feet per year. A program outline in the General Program and Alternative Appendix would conserve about 270,000 acre-feet per year of water now consumed by phreatophytes or lost in conveyance in the lower Colorado River downstream from the Mohave Valley. This program would have salinity benefits. All feasible water conservation measures are expected to have been implemented by 1980 according to the plan in the General Program and Alternatives Appendix.

The projected water supply assumed to be available in the Lower Colorado Region is inadequate to support the development recommended by this study. In order for this development to be realized, augmentation must occur. Although augmentation is called for in the regional framework plan, no salinity analysis was developed in regard to the amount of augmentation water that might be available at points within the Colorado River.

If no salinity improvement measures are implemented the result in 2020 will be a salinity concentration of 1350 mg/l at Imperial Dam. A number of federal and state agencies have estimated the salinity at Imperial Dam to be in the range of 1150 to 1340 mg/l with full development of the river. The net effects of the salinity program assumed for the Upper Colorado Region, and the salt reduction and water conservation program in the Lower Colorado Region are summarized in Table 48.

Table 48 - PROJECTED CONCENTRATIONS OF DISSOLVED SOLIDS
IN THE LOWER COLORADO RIVER
(mg/l)

Location	1965	1980 Without Programs	1980 With Programs	2000 Without Programs	2000 With Programs	2020 Without Programs	2020 With Programs	Percent Increase 1965-2020 Without Programs	Percent Increase 1965-2020 With Programs
Colorado River									
at Lee Ferry, Arizona	586	650	560	760	580	820	630	40	8
below Hoover Dam	734	950	860	1,010	810	1,050	850	43	16
below Parker Dam	726	980	870	1,140	870	1,150	880	58	21
At Imperial	839	1,260	1,100	1,290	980	1,350	1,030	61	23

Assuming complete control of Blue Springs (not included in the analysis presented in Table 48), the concentration of dissolved solids at Imperial Dam would decrease from 1,030 to 960 mg/l in 2020.

Due to the intense use of surface, ground, and future Central Arizona Project waters, coupled with the non-degradability of salts and the absence of significant outflow from the Central Arizona area, a salt balance cannot and will not be maintained, and the ground water mass will serve as the ultimate repository for salts. Projected increased water uses and additional annual salt loads conveyed by the augmentation waters requires an intensive salinity management program in the Gila Subregion. The "Ground Water Quality Management Program" that follows presents more details of this need.

Various other salinity improvement measures are available for the potential management of salinity. Although these control measures are technically feasible, various other factors, including economic feasibility and legal and institutional constraints, limit the present practicality of most. Potential control meausres which may be considered in the Basin are listed in Table 49.

Of the water conservation measures listed in Table 49, the most promising methods for the Lower Colorado Region in the future will be suppression of evaporation, vegetative management for increased water yield, and water augmentation measures such as water importation or desalination.

Table 49 - POTENTIAL SALINITY IMPROVEMENT MEASURES

I. Measures for Increasing Water Supply

- A. Water Conservation Measures
  - 1. Vegetative Management for Increased Water Yield
  - 2. Suppression of Evaporation
  - 3. Improved Irrigation Efficiency
    - (a) By land selection
    - (b) By irrigation management
- B. Water Augmentation Measures
  - 1. Weather Modification
    - a. Fresh Water Sources
    - b. Demineralized Sea Water

II. Measures for Reducing Salt Loading

- A. Control of Natural Sources
  - 1. Natural Discrete Sources
    - a. Evaporation of Discharge
    - b. Injection into Deep Geological Formations
    - c. Desalination
    - d. Suppression of Discharge
    - e. Reduction of Recharge
  - 2. Natural Diffuse Sources
    - a. Surface Diversions
    - b. Reduced Groundwater Recharge
    - c. Reduced Sediment Production
- B. Control of Man-Made Sources
  - 1. Municipal and Industrial Sources
    - a. Evaporation
    - b. Injection into Deep Geological Formations
    - c. Desalination
  - 2. Irrigation Return Flows
    - a. Land Selection
    - b. Canal Lining
    - c. Improved Irrigation Efficiency
    - d. Drainage
    - e. Treatment of Return Flows

Research should be continued to develop economical methods for suppressing the large evaporation losses. No practical methods are available since the mono-molecular films developed to date are expensive and become ineffective when broken up by wind or biological activity.

Without flow augmentation and/or salinity improvement measures significant costs will result to the Lower Colorado and California Regions' economy. The salinity improvement measures which will produce the most significant effects for the money expended are located in the Upper Colorado Region. Those outlined for the Lower Colorado Region would have their effect in reduced salinity levels in the system, but flow augmentation appears necessary if the Lower Colorado Region were to maintain nearly constant salinity concentrations while meeting projected water supply needs.

The costs, both direct and indirect, to the Lower Colorado and California Regions economies without salinity improvement are estimated to exceed more than $25 million annually in 2010, according to a recent study.[48] Direct penalty costs are yield reductions for irrigated agriculture, treatment costs for industrial users, and the acceptance of undesirable effects or water softening expenditures for municipal users. Indirect costs are spin-off effects on the secondary or supporting industries. Since the modified OBE-ERS projections for the Upper Colorado, Lower Colorado, and California Regions are substantially greater than those used in the study referenced above, it is estimated that the salinity penalty costs (the reductions of economic returns based on the use of water poorer in quality than present quality) will greatly exceed $25 million per year in 2020.

Capital investment costs for controlling LaVerkin Springs consists of an $11.4 million outlay during the 1965-1980 time-frame. Annual operation, maintenance and replacement costs for LaVerkin Springs is estimated at $110,000. These costs are for that portion of the Colorado River Basin Salinity Improvement Program located in the Lower Colorado Region. These costs are not included as a part of the total Regional program development costs delineated in the Lower Colorado Region Framework Plan.

The cost of desalting municipal effluents at Las Vegas is considered as part of the water supply costs presented in the Municipal and Industrial Water Supply Appendix.

Streamflow Management Program

Water quality improvement by means of stream flow management is limited in the Lower Colorado Region, under present legal and institutional environments. Water quality is most critical during periods of low runoff when consumptive uses require diversion of the entire stream-flow at many locations, particularly on minor tributary streams and at major diversion points.

The maintenance of minimum flows for water quality control purposes is not recognized as a beneficial use of water in the water rights laws of any state in the Region. The availability of water to maintain water quality and meet the criteria established by the state water quality standards depends exclusively on flows released to meet other downstream uses. The Colorado River Compact and other compacts and treaties require delivery at specified points, of specified quantities of water over given periods of time. Except for possible compact and treaty commitments under present state and federal water laws in the Region, the entire flow of a stream could be periodically removed leaving the stream dry. Even if flows were released for low-flow augmentation, the water could be diverted for recognized uses under present water law.

The establishment of firm base flows for maintenance of water quality standards depends upon legislative changes by the states and federal government recognizing water quality control as a beneficial in-stream water use and purchasing existing water rights or importation.

In addition to the area being one of short water supply and the problems with state water laws, present legal and institutional constraints involving the entire Colorado River Basin inhibit implementation of a streamflow management program with respect to water quality considerations. These constraints involve the Colorado River Compact and the other compacts and treaties as well as the many state and federal programs responsible for the management of the Colorado River.

Enhancement of water quality as an incidental use in increasing below storage reservoirs. During periods of low runoff, releases are made from the reservoirs to downstream uses. Flow regulation afforded by existing reservoirs reduce the sediment load and the large variations in salinity concentration. To date, these benefits have been spinoffs from the primary objectives of the multiple-purpose projects. The stream reaches enhanced have, in many cases, been short since diversions to primary uses are often only a short distance below the reservoir.

If maintenance of minimum streamflow conditions for water quality control becomes recognized as a legitimate use, water resources management could provide for the optimum combination of quality and quantity for the available supply. However, in no case can flow augmentation be considered a substitute for waste treatment for sources that can be practicably treated.

Existing legislation permits water quality control storage to be included as a project use under federal developments. Planning for future reservoirs should provide for broad management objectives and give consideration to including storage for water quality objectives.

In considering a streamflow management program, the effects of stream regulation on an entire river basin would have to be an integral part of any region-wide or basin-wide water quality management scheme. Through such an approach, which might be possible using systems analysis methods, the optimum combination of wastewater discharges and water diversions could be predicted.

Before such a method could be considered for the Lower Colorado Region, data-gathering programs would have to be substantially expanded to overcome the paucity of information describing the physical, chemical, and biological nature of water quality; the flows and hydraulic characteristics of steams; the location, timing, quality and quantity of diversions, residual waste dishcarges and irrigation return flows; and various other factors needed for computing water quality projections.

Additional research is needed to provide a better understanding of the hydrologic and quality relationship between ground water and surface water. Research is also necessary to simulate changes in water quality which occur in the major reservoirs, in order to provide a knowledge of the quality to be expected in the impoundments and also downstream as the result of reservoir releases. Results of such efforts would assist in developing criteria for reservoir operation as part of the overall water quantity and quality management program.

Ground Water Quality Management Program

The complexity of ground water quality has been illustrated by a discussion in the Present Water Quality section of the quality variances in the different geographical locations and geological formations. In one well alone, large quality variations were observed between the upper and lower depths. Quality of the ground water is susceptible to change by the potential pollutants derived from activities of man. Of prime importance to the Region and especially the Gila Subregion is the need to maintain a salt balance.

The recharge of new waters into ground water reservoirs must come from the inadequate sources of runoff, from precipitation in adjacent mountain ranges, infiltration of applied irrigation water from surface water sources, underflow from upstream basins, and direct penetration of precipitation. Because recharge from these natural sources is not sufficient to meet water supply needs, importation of water is planned to augment the declining ground water supply.

In the past, the availability of water has always been the primary consideration of development and water quality implications have received little or no consideration. Water quality, especially salinity, is becoming equally as important. An awareness of the detrimental economic effects of increased mineralization on agricultural, municipal, and industrial users is the main reason for this change in emphasis.

Future management will be vitally needed to control, protect, conserve, distribute, and use the ground water resources with due concern for water quality. Future imports of water will bring in salt loads and, with continued reuse of the water, the residual salts will accumulate in the area. The water quality impacts of these pollutants have not been quantified or evaluated.

Various schools of thought exist in regard to the type of ground water management organizations. In Israel, a master plan is being implemented for total control and development. The position of the State of California [7] appears applicable to the Region and is quoted in part as follows:

> "....The State does not contemplate ground-water basin management. The State's role is to develop and transport water to major areas of use, within ground water basin operational concepts; but it will be the responsibility of local districts to implement ground-water basin management.
>
> Let us consider planning for ground-water basin management from the local agency standpoint. First, the physical facts must be determined.....
>
> Secondly, the physical facts must be tempered with practical economics to formulate a management plan.....
>
> To be fully effective, management should provide a right to a water supply, irrespective of source. This would enable the integration of both surface and underground storage facilities to provide the most economical overall water service, which includes both development and transmission.....
>
> Finally, an agency must be established with sufficient powers to undertake broad-scale ground-water basin management.....
>
> The matter of granting appropriate powers to a local agency to integrate all sources of water into a planned pattern of overall water use raises serious questions concerning the adequacy of current concepts of water rights. Our existing water-right concepts attach a <u>property right</u> to the use of water from a particular source. However, the management of total resources to meet all economic demands cannot be efficiently accomplished under such a system.

It will be the role of the Legislature to clear the way for the establishment of appropriate districts endowed with adequate powers to undertake full-scale water resources management.....It will be the responsibility of each of us to embark on an education program designed to create the appropriate political atmosphere for acceptance of the broader concept of the use of ground-water basins in broad-scale water resources management."

The above quoted ground-water management concepts again emphasize water quantity and not water quality. With recognition of the importance of the water quality aspect that must be added to this framework, the total ground water management plan needed in the Region becomes enlarged. Water quality is a new dimension which will influence future water distribution. In order to implement a proper management program, the quality characteristics of ground water must be known. Much research and investigation is needed to answer the many unknown facets of quantity-quality relationships.

Ground-water resources should be monitored and inventoried with particular consideration to quality characteristics to prevent saline ground waters from mixing with high quality surface water, to continue research for cheaper methods of desalting, to determine the fate of bacteriological and pesticide pollutants, and to continue the study of reuse of water and the safe subsurface disposal of the concentrated wastes.

When the above considerations are evaluated, plans can then be developed for a ground water quality management program which should be linked with ground and surface water management programs. Basic objectives of the program would be to develop the institutional arrangements and organizational structure for integrated management of the total water resources.

1. Planning should be on a Regional basis and should fit into an overall comprehensive plan.

2. Planning should evaluate and optimize use of ground and surface water with due consideration to quality implications. For the protection of high-quality ground water reservoirs and aquifers, for example, regulations would affect:

   a. Application of waters to recharge areas.
   b. Application of waters to irrigated areas; and
   c. Deep well injections of wastes or other methods of waste disposals which could infiltrate into

the subsurface water supplies. Systems analysis techniques would be used as a tool to guide decisions.

3. All feasible alternatives should be evaluated, including reclamation and reuse of wastewaters and desalination.

4. Social and economic goals and objectives should be clearly defined including ground water quality standards, where applicable.

Implementation of the program would involve legal and institutional changes. Present legal and institutional constraints must be evaluated in terms of a changing environment where use of water, availability of resources, and concentration of people will dictate possible change.

Wastewater Treatment Program

The suggested program for improved wastewater treatment consists of six parts: (1) construction of treatment works to meet the existing backlog of treatment needs; (2) construction of additional facilities to meet the demands of population growth, industrial expansion, and increased recreational activities; (3) replacement of obsolete plants and equipment; (4) improved operation, and maintenance of treatment facilities; (5) research to find more effective and efficient means of treatment; and (6) upgrading treatment systems to meet new treatment requirements.

Progressively higher efficiencies of BOD removal through secondary treatment are projected throughout the sutdy period. It is assumed that a minimum BOD removal of 85 percent will be required by 1980, 90 percent by 2000, and 95 percent by 2020. Removal of dissolved salts from municipal and industrial effluents for the specific purpose of alleviating salinity conditions is doubtful. The advanced wastewater treatment facility proposed for Las Vegas will effect salinity reductions because of the desalting of wastewater recycled for further use.

It is also assumed that conventional treatment will continue to provide the same degree of nutrient reduction. The tertiary treatment schemes for Las Vegas, Phoenix and Tucson should remove most of the nutrients present in the wastewater.

Due to the complexity of industrial waste treatment, it is difficult to forecast future methods of waste disposal for industries. Technological advancements should help in efforts to reduce pollution from industrial wastes. Protection of the environment should be considered in the design of new industrial installations.

The practice of treating municipal and industrial wastes in a common treatment plant should be continued where feasible. More efficient and economical treatment of municipal wastes may be accomplished in some areas by the establishment of multi-community collection and disposal districts.

The change in the magnitude of rural-domestic wastes does not appear to warrant major changes in waste handling practices for rural-domestic sources. Continued care in the disposal of waste from the rural-domestic population will be necessary to protect surface and ground water supplies.

Adequate waste disposal facilities should be required at all developed recreation sites. All boats equipped with toilets should have holding tanks. Facilities for disposing holding-tank wastes should be required at principal docking areas.

Federal regulations for financial assistance for the construction of wastewater treatment works now require that the treatment facility be an integral part of a regional or area plan for water quality management.

Based on the 85, 90 and 95 percent projected BOD removal efficiencies, the five percent reduction in TDS and the 15 percent decrease in phosphorus, the estimated wastes remaining after treatment from municipal and manufacturing sources are shown in the following table:

Table 50 - ESTIMATED RESIDUAL 1/ WASTES FROM MUNICIPALITIES AND MANUFACTURING INSTALLATIONS
(tons/year)

	1965	1980	2000	2020
	-- BOD --			
Lower Main Stem Subregion	4,800	3,800	4,700	3,800
Little Colorado Subregion	1,000	700	600	400
Gila Subregion	15,900	14,900	15,200	11,100
Lower Colorado Region	21,700	19,400	20,500	15,300
	-- TDS --			
Lower Main Stem Subregion	29,600	50,600	94,900	156,800
Little Colorado Subregion	7,200	10,800	14,200	16,700
Gila Subregion	169,000	248,800	375,800	542,700
Lower Colorado Region	205,800	310,200	484,900	716,200
	-- P -- 2/			
Lower Main Stem Subregion	380	620	1,170	2,010
Little Colorado Subregion	80	140	180	210
Gila Subregion	1,740	2,430	3,950	6,040
Lower Colorado Region	2,200	3,190	5,300	8,260

1/ After secondary treatment.
2/ Phosphorus computed for municipal wastes only.

Advanced methods of wastewater treatment are proposed to reclaim for reuse the effluents from the secondary treatment works serving the urbanized areas of Phoenix, Tucson, and Las Vegas. Recycling, after tertiary treatment, will augment other water sources thereby providing part of the municipal and industrial water supply needed in these areas. 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.

The program suggested for metropolitan Las Vegas, Nevada is shown in Figure 5. The current pollution problem in Las Vegas Bay should be eliminated by the construction and operation of a tertiary treatment plant varying in size from 50 mgd

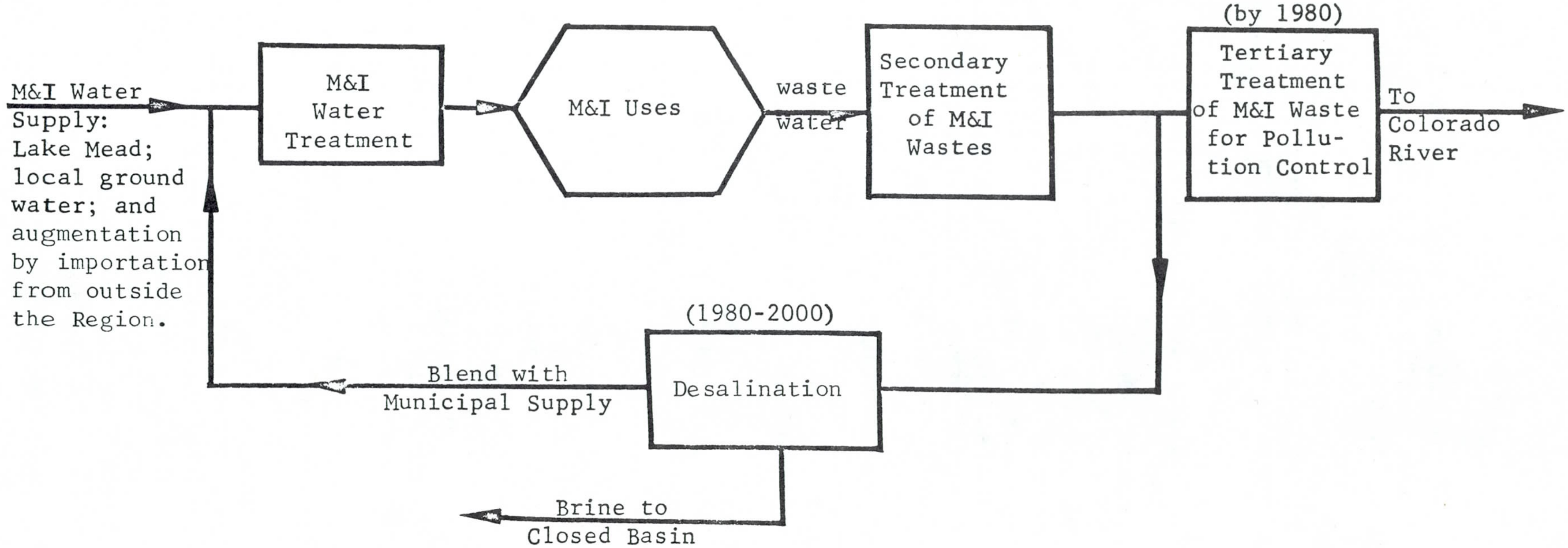


Figure 5--Schematic Diagram of Program for Water Use and Reuse for Metropolitan Las Vegas, Nevada

capacity in 1972 to 120 mgd capacity in 2000. The tertiary plant could remove nearly all of the suspended solids, color, odor, and bacteria, most of the BOD, detergents, and phosphorus, and a large fraction of the nitrogen. Scheduling of the tertiary plant is suggested for the 1965-1980 timeframe. The desalination plant could be included in the 1980-2000 timeframe as a means of meeting part of the municipal and industrial water supply needs.

The water quality control program suggested for the Gila Subregion is tied to major reuse facilities for metropolitan Phoenix and Tucson. The suggested program for Phoenix is shown in Figure 6. Wastes are to be treated to an equivalent secondary level and the effluent applied to the land to effect additional removals by ground-water recharge. A pilot project that is presently carrying out this concept is achieving encouraging results. Water made available from the ground-water recharge would be available for unrestricted irrigation use in the volumes shown in Figure 6.

An import water source would be necessary according to the framework plan during the 2000-2020 period to meet projected water needs and reduce ground-water overdraft. It is estimated that after augmentation about 300,000 acre-feet per year return flow from drainage of irrigated lands would be available near Buckeye, Arizona. The dissolved solids concentration of the return flow is estimated to be about 4,000 mg/l. A nuclear dual-purpose desalting plant of 150 mgd capacity could treat the return flows.

The suggested program for metropolitan Tucson is similar to that described for Phoenix. The tertiary treatment effluent would be diverted to a public aquatic park complex and to ground-water recharge as shown in Figure 7. Tertiary treatment would reduce the nitrates entering the ground-water supply, a problem that is increasing in the ground water north of Tucson. The water reuse programs for both Phoenix and Tucson are included in the 1965-1980 timeframe.

Future water depletions have been estimated by the Water Resources Workgroup on a subregional basis. Inasmuch as the depletions have not been disaggregated to smaller hydrologic units, no estimate can be made of the future flow at points within the river system except for the lower Colorado River. Due to this and the high degree of water reuse expected, predictions of future water quality cannot be made showing the effects of residual wastes on stream flows. It is not anticipated that there will be any streamflow below many communities due to direct diversion of effluents for other uses.

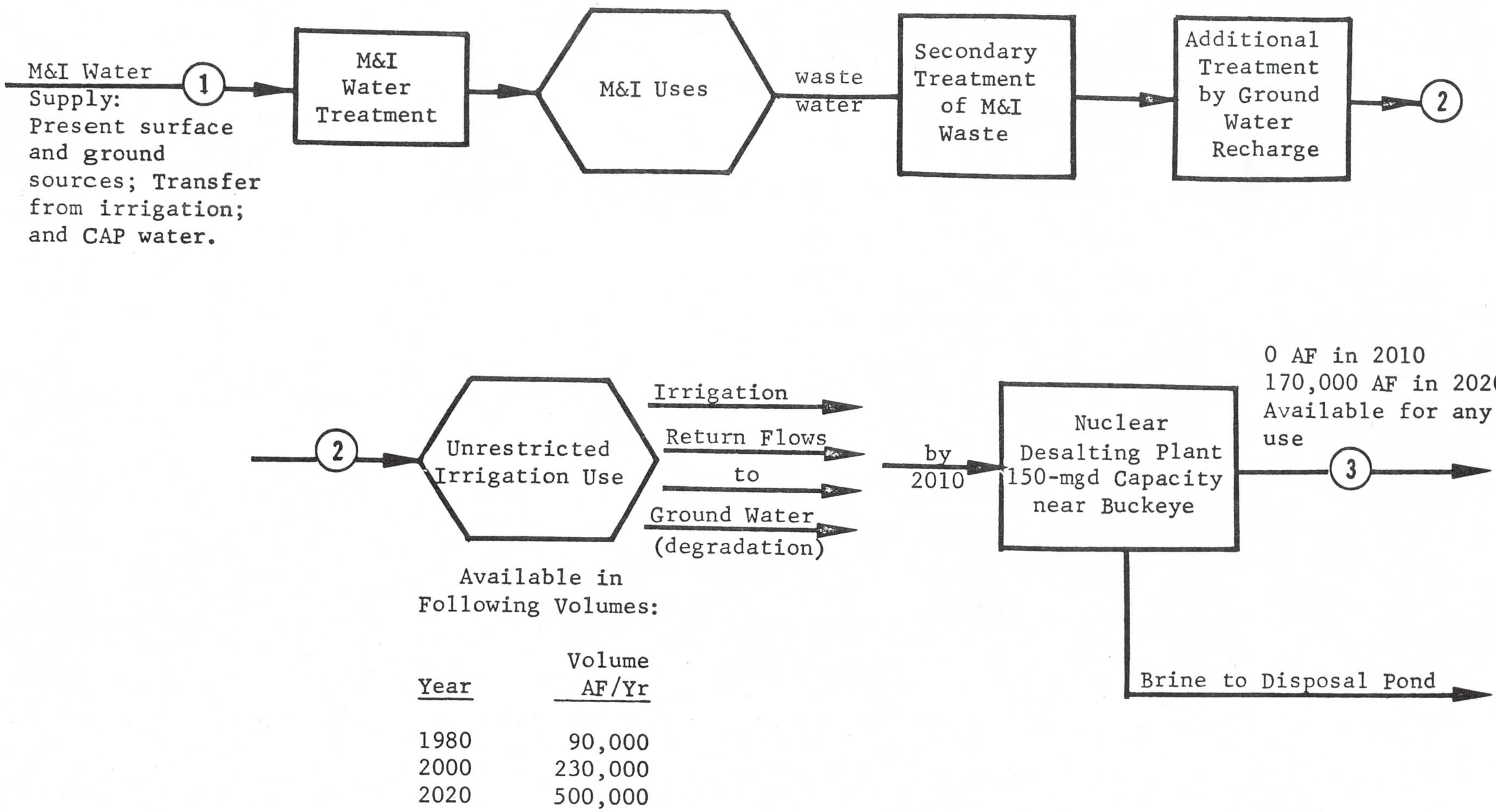


Figure 6--Schematic Diagram of Program for Water Use and Reuse for Metropolitan Phoenix, Arizona

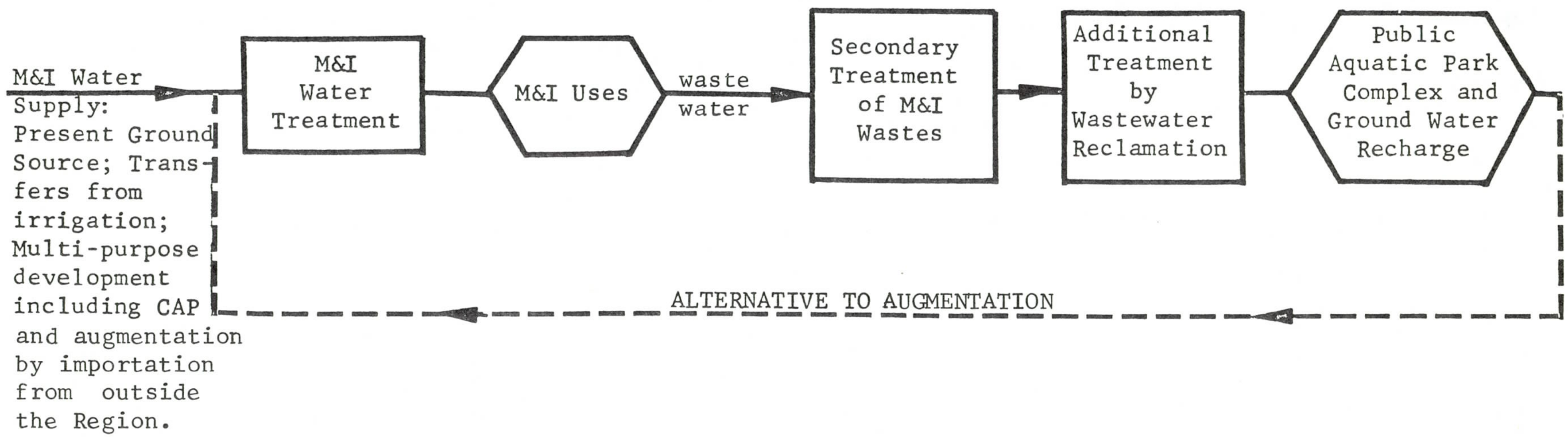


Figure 7--Schematic Diagram of Program for Water Use and Reuse for Metropolitan Tucson, Arizona

The impact on water quality will be largely dependent on the concentration of waste-producing activities within limited areas and the subsequent reuse or discharge of effluents. Special attention to waste disposal will be required in recreational areas in order to accommodate future growth yet avoid severe effects on the quality of water needed for recreation. In view of the increased potential for nutrient problems, it is quite probable that advanced methods of wastewater treatment may be needed in some areas other than Phoenix, Tucson and Las Vegas to remove nutrients from effluents.

Adequate operation and maintenance with active supervision of treatment works must be provided by fully qualified personnel. In addition to ability and perserverance, a knowledge of the concepts involved in the treatment process is essential. The operators must understand wastewater characteristics and the functions of various units. They must be able to perform essential analytical tests. Technical proficiency varies from an understanding of basic fundamentals to a highly technical competence, depending on the methods and complexity of treatment used. Adequate salaries for operators are necessary to encourage and keep better qualified individuals in this type of work.

Training and education programs should be established to provide trained personnel who are skilled in plant operation, maintenance and laboratory techniques. Wastewater treatment plant laboratory facilities should be adequate so that reliable analyses can be made to determine the efficiency and competency of plant operation.

Arizona, New Mexico, and Utah have voluntary programs for the certification of wastewater treatment plant operators. The voluntary programs provide those plant operators desiring to learn, the opportunity to receive necessary training. The need exists for legislation requiring mandatory training and certification. Most Region states have recognized this need, and some have established committees to study and propose the necessary legislation. Federal assistance is available to support training programs through the Manpower Development Training Act and the Clean Water Act of 1970.

Continued surveillance and inspection of the operation of waste treatment plants are necessary for the purposes of locating and identifying existing and potential pollution problems. State water pollution control agency staffs should be increased to provide better control over operations and to provide routine technical assistance to the communities involved. This need is greatest for the smaller towns.

Wastewater treatment research efforts for the Lower Colorado Region should be directed towards finding better ways to remove nutrients, dissolved salts, toxicants and other chemical pollutants.

Costs of wastewater treatment are based on cost data presented in the 1968 Federal Water Quality Administration report, "The Cost of Clean Water."(47)

The capital investment costs detailed in the above report are for secondary treatment or its equivalent. This is assumed to mean 85 percent BOD removal--the 1980 minimum level prescribed in this Appendix. For municipal wastes, it is assumed that the years 2000 and 2020 requirements for 90 and 95 percent BOD removal can be met at the same unit costs as 85 percent in 1980 due to improved technology.

In contrast, higher levels of treatment for industrial wastes were not assumed to remain at a constant cost rate due to new requirements after 1980 to remove additional pollutants which will offset any savings from technological improvements. The cost of industrial waste water treatment is estimated to increase 50 percent between 1980 and 2000 and 100 percent between 2000 and 2020.

The federal and non-federal split in costs is based on present formulas for federal aid to municipalities. It was assumed that the states would develop programs for matching grants to municipal governments. This would provide 55 percent federal, 20 percent local, and 25 percent state funding. Recreation costs are distributed according to the nature and ownership of the recreational facility and includes only water-based recreational activities. Costs for animal waste abatement needs assume only minimal control measures.

Table 51 - CAPITAL INVESTMENT COSTS FOR WASTEWATER TREATMENT WORKS
($ Million)

	1965-1980		1980-2000		2000-2020	
	Fed	Non Fed	Fed	Non Fed	Fed	Non Fed
Lower Main Stem Subregion						
Municipal Secondary Treatment	9.0	7.0	11.0	9.0	18.0	14.0
Industrial Secondary Treatment	0.0	2.0	0.0	4.0	0.0	10.0
M&I Tertiary Treatment 1/	12.2	10.0	2.3	1.8	0.0	0.0
Recreation Wastes	0.6	0.6	0.9	0.5	1.7	1.0
Animal Wastes	0.0	0.1	0.0	0.1	0.0	0.1
Subregion Total	21.8	19.7	14.2	15.4	19.7	25.1
Little Colorado Subregion						
Municipal Secondary Treatment	2.0	1.0	2.0	1.0	1.0	1.0
Industrial Secondary Treatment	0.0	1.0	0.0	1.0	0.0	1.0
M&I Tertiary Treatment	0.0	0.0	0.0	0.0	0.0	0.0
Recreation Wastes	0.1	0.2	0.2	0.3	0.2	0.5
Animal Wastes	0.0	0.1	0.0	0.1	0.0	0.1
Subregion Total	2.1	2.3	2.2	2.4	1.2	2.6
Gila Subregion						
Municipal Secondary Treatment	28.0	23.0	28.0	23.0	39.0	31.0
Industrial Secondary Treatment	0.0	13.0	0.0	17.0	0.0	41.0
M&I Tertiary Treatment 2/	0.9	0.7	1.2	1.0	1.2	1.0
Recreation Wastes	1.1	0.9	1.5	1.0	2.7	1.6
Animal Wastes	0.0	1.1	0.0	0.5	0.0	0.5
Subregion Total	30.0	38.7	30.7	42.5	42.9	75.1
Lower Colorado Region	53.9	60.7	47.1	60.3	63.8	102.8

1/ Tertiary treatment cost for Las Vegas only - does not include desalting plant.
2/ Land treatment processes at Phoenix and Tucson.

The major cost of the wastewater treatment program will occur through operation, maintenance, and replacement costs rather than from the capital investment for construction.

Although the federal government does not help to pay the cost of operating municipal plants, there will be a federal cost for operation, maintenance and replacement of some wastewater treatment facilities due to federal ownership.

Table 52 - ANNUAL OPERATION, MAINTENANCE AND REPLACEMENT COSTS FOR WASTEWATER TREATMENT
($ Thousand)

	1980		2000		2020	
	Fed	Non-Fed	Fed	Non-Fed	Fed	Non-Fed
Lower Main Stem Subregion						
Municipal Secondary Treatment	90	800	220	1,950	430	3,900
Industrial Secondary Treatment	0	400	0	1,100	0	3,100
M&I Tertiary Treatment	0	1,200	0	5,400	0	7,600
Recreation Wastes	10	10	15	5	40	20
Animal Wastes	100	40	0	80	0	120
Subregion Total	100	2,450	235	8,535	470	14,740
Little Colorado Subregion						
Municipal Secondary Treatment	20	150	30	240	30	280
Industrial Secondary Treatment	0	40	0	70	0	90
M&I Tertiary Treatment	0	0	0	0	0	0
Recreation Wastes	2	3	4	6	4	12
Animal Wastes	0	4	0	8	0	8
Subregion Total	22	197	34	324	34	390
Gila Subregion						
Municipal Secondary Treatment	250	2,000	550	4,500	990	8,600
Industrial Secondary Treatment	0	1,600	0	4,300	0	10,900
M&I Tertiary Treatment	0	1,200	0	2,200	0	3,700
Recreation Wastes	15	15	35	15	65	35
Animal Wastes	0	330	0	500	0	670
Subregion Total	265	5,145	585	11,515	1,055	23,905
Lower Colorado Region	387	7,792	854	20,374	1,559	39,035

Thermal Pollution Control Program

Thermal pollution control programs must consider the rejected cooling waters from electric power generation and other industrial operations; the warmed wastewaters from municipalities; the return flows from irrigation which have been warmed by the sun on fields; the impoundment of surface waters; the depletion of streamflows for irrigation, industrial applications, and other uses; along with other hydrologic and climatic conditions.

Data are not adequate at this time to develop a water quality management scheme for temperature control. Research must be continued to provide a further understanding of the causes, effects, and control of thermal pollution in order to find more effective and economical means of solving the problems.

Thermal control measures will have an impact on the development of water-quality management programs for other parameters, e.g., reduction of stream temperature improves the dissolved oxygen resources of a stream, and potential for growth of aquatic plants is lessened as stream temperatures are lowered.

In order to keep stream temperatures within the limits set by the state standards, the discharge of waste heat from major point sources should be controlled. A description of heat dissipation methods for electric power generating facilities is presented in the Electric Power Appendix. Any method that provides air-water contact for cooling, such as cooling towers or cooling ponds, removes about 75 percent of the heat through evaporation and the remainder through conduction-convection. As water is vaporized, heat is consumed at the rate of 1000 BTU per pound of water evaporated. Almost all of the heat is taken from the water that remains, thereby lowering its temperature. Similar cooling methods, adapted to volume and temperature differences, would probably be used for manufacturing or other industrial operations.

Potential uses of waste heat for agricultural, industrial and other beneficial purposes should be explored further. Use of this heat energy may result in economic and resource conservation benefits and serve to keep the heat from becoming a waste product with its subsequent effects on the environment.

Watershed Management Program

Methods of controlling or partially controlling erosion and sediment may be classified as land treatment and structural measures. Land treatment includes such measures as critical area planting, contouring, seeding and terracing, and brush control; structural measurs include channel lining, drop structures and debris basins.

The following table shows that if the land treatment is applied and structural measures installed that are suggested in the Watershed Management Appendix there will be a significant reduction in sediment yeild within the Region. The figures in Table 53 cannot be applied directly to suspended load data to determine future loads, but they do indicate the trend. If sediment yield will be reduced so must the sediment in streams. The important point here is that while most if not all other pollutants are increasing throughout the study period, sediment in streams should be decreasing.

Table 53 - REDUCTION IN SEDIMENT YIELD EXPECTED DUE TO LAND TREATMENT AND STRUCTURAL MEASURES

Subregion	1980	2000	2020
	-- Percent	Reduction	--
Lower Main Stem	0.5	2.5	5.0
Little Colorado	2.1	10.5	21.0
Gila	1.4	7.0	14.0
Lower Colorado Region	1.3	6.5	13.0

The reasons that sediment yield reduction figures cannot be applied directly to compute suspended load reduction are numerous. An important reason is that in most of the streams there is an unlimited source of sediment already available. Therefore, even if the sediment yield from the watershed to the stream was reduced to almost nothing, some of the available supply of sediment in the stream bed would be picked up and carried as suspended load.

An evaluation of the relationship between suspended sediment and the dissolved solids loading of streams might provide a determination as to whether soil erosion and other sediment controls may be useful in reducing the dissolved solids loading of streams in the Region. Such a study would resolve whether or not a substantial portion of the total salinity load of the streams is associated or originates with the solution of minerals from the large volume of sediment transported by the streams.

Agricultural Wastes Management Program

Two major water-quality pollutants originating from agricultural operations are mineral salts and sediments. Measures for alleviating these forms of pollution have been outlined in the programs for salinity control and watershed management.

This section describes programs for minimizing the effects from agricultural chemicals and animal wastes.

Better management and conservation practices should reduce many adverse effects on water quality resulting from agricultural operations. The frequency of application and the amount of agricultural chemicals applied to farmlands and forests should be kept to the minimum required for control purposes. Present programs of the U.S. Department of Agriculture and Environmental Protection Agency directed toward safety in handling and applying agricultural chemicals should be continued toward this end.

The fate, persistence and distribution of agricultural chemicals needs to be better understood. Expanded monitoring programs to determine the presence and nature of pesticides and plant nutrients in surface and groundwater are needed.

More knowledge is needed of the effects of long-term exposure of pesticides on biological forms. Research is necessary for the development of criteria for pesticides in water. Further research into the development of effective, short-life pesticides or suitable substitutes is required.

The relationships which exist between surface applications of various forms of nitrogen from fertilizers and from the possible future use of sewage effluents for irrigation and observed high nitrate concentrations in water wells should be studied. The research should include studies control of possible means to control ground-water pollution by such surface applications.

Research is needed to develop economically feasible methods for the treatment of both surface and subsurface drainage from irrigated agricultural areas. The method of treatment would depend upon the particular geographical area and the associated water quality degradation resulting from dissolved solids, nutrients, pesticides, or a combination thereof.

The proper selection of livestock feedlot locations away from streams and urban and suburban areas is necessary to minimize adverse environmental effects. The quantity of feedlot runoff can be decreased by preventing outside surface water from entering the confinement area. Methods of disposing solid and liquid wastes should avoid pollution of surface and ground waters.

Most attempts at treating wastewater from livestock holding facilities by conventional wastewater treatment methods, including lagoons, have generally been unsuccessful. The use of lagoons for the disposal of animal wastewaters is under study by the Department of Agriculture as well as by several state agricultural experiment stations and universities. Modifications in design, use, loading, mechanical aeration, and other operational changes are beginning to show some promise for providing better water pollution control.

Important factors affecting costs of waste disposal include size and location of feedlot, soil characteristics, and the manner of disposal of solid wastes and effluent. National estimates[47] of the costs of installing waste treatment facilities vary considerably. The few feedlots equipped with treatment lagoons indicated construction costs ranging from $1 to $5 per head capacity. Construction included fencing, grading lots for proper runoff, excavating lagoons, and installing an irrigation system to distribute the effluent to surrounding cropland.

Contingency Plan for Controlling Accidental Spills of Hazardous Materials

The Water Quality Improvement Act of 1970 required the establishment of a national contingency plan for the control of accidental spills of hazardous materials. The Environmental Protection Agency has primary responsibility for the control of spills to inland waters.

The national plan, in turn, requires regional plans which are not yet complete. Interagency Response Teams consisting of members from federal and state agencies are to be established for the regions. The function of the Response Team will be to provide consultation on methods of cleaning up the spilled material. In the event the person or persons refuse to take action, or if responsibility cannot be immediately determined, corrective action is to be initiated by the Response Team's On-Scene-Commander.

A prelimary contingency plan has been developed by the Environmental Protection Agency for the Colorado River Basin. A major component of this plan is a pollution warning system whereby responsible local, state and federal officials are alerted. Downstream water users are to be notified as necessary in order that they may take protective measures. Other features of the plan include maps delineating access points to basin streams and listings of local suppliers of products that may be needed for pollution control or clean-up. This plan needs to be finalized. States should consider the development of complementary contingency plans.

One of the Lower Colorado Region's pollution surveillance problems is the detection of spills of pollutants into streams. Reporting of spills is often delayed by days or weeks. Automatic continuous recording would facilitate detection of such problems. Research should be supported which could lead to the development of reliable automatic continuous recording stream monitors with data-telemetering capabilities.

Water quality and pollution determinations by aerial survey offer one of the quickest and least costly methods known at this time. If the method can be developed for regular use, it would be of considerable value in the tracing and following of slugs of toxic or hazardous material resulting from accidental spills or dumpings.

Effective methods of containment control and clean-up of oil spilled on rivers and streams could be determined through research studies. Research should include information on emplacement and maintenance in remote canyon areas. Effects of dispersal agents on suitability of water in streams and impoundments for domestic, agricultural, and fisheries uses should be evaluated.

HEALTH FACTORS

CHAPTER C - HEALTH FACTORS

Four broad categories are used to cover this topic. These are epidemiological assessment, drinking water supplies, disease vector control, and environmental health analysis. The epidemiological assessment is an evaluation of the occurrence and trends for water-related diseases. Disease vector control discussion is directed toward the known and potential vectors in the Region and the steps and means being taken to control them. Drinking water supplies are related to adequacy of treatment, surveillance, source protection and other such factors necessary to insure safe potable water. The environmental health analysis reviews and discusses solid waste disposal, air pollution, radiological health, and the recreational health considerations of water resources development.

EPIDEMIOLOGICAL ASSESSMENT

Water-borne Disease

Water has long been recognized as a potential vehicle for the transmission of organisms of various human enteric diseases. Of the numerable diseases potentially transmitted by this route, a total of six were reported in the Region during 1965. The total number of cases related to the six diseases is about 970. Table 54 lists these diseases and the reported number of incidents.

An important reference document recommended for those concerned with the health aspects of water and land management will be "Health Guidelines for Water Resources and Related Land Management." These guidelines are being prepared by the U. S. Public Health Service for use in reviewing individual water resources projects and are also applicable for general planning purposes. The guidelines will be available at the Regional Offices of the Department of Health, Education, and Welfare when completed.

Table 54 - REPORTED CASES OF POTENTIALLY WATER-BORNE DISEASES IN THE LOWER COLORADO REGION -- 1965 1/

Disease	Cases Reported
Amebiasis	209
Encephalitis	17
Hepatitis	410
Salmonellosis	156
Shigellosis	155
Typhoid	15

1/ "Morbidity and Mortality", National Communicable Disease Center, 1965.

The number of reported cases for the entire United States was 67,483. The Region total represents 1.5 percent of this which compares unfavorably with the expected percentage based on population. The Regional population is less than 1 percent of the national which indicates that the rate of waterborne disease occurrences in the Region is over 150 percent of the national rate.

Epidemiological data are not available to indicate just what percentage of the reported cases were a result of waterborne infections. In general, however, the mode of transmission of these disease is by food and/or personal contact rather than by water. The present vector control programs, drinking water supplies and recreational areas are not necessarily incriminated by the high rate of such diseases. The fact that the infectious diseases are present emphasizes the need for continued vigilance in these areas.

The "high" incident rate may, in part, be explained by the large Indian population. In general, the housing, water systems and sanitary facilities on the Indian Reservations are sub-standard and it is in just these areas that unsanitary practices contribute to incidence of infective parasitic disease. Several programs are underway to improve this situation. The U. S. Public Health Service is constructing potable water systems and waste disposal systems. The Bureau of Indian Affairs has established housing programs and operates schools.

The outlook for the future is for the most part unpredictable in this area. It is a certainty that increased population pressures on recreational areas will increase the hazard for transmission of disease by this route. Larger populations will also result in a proportionate increase in wastewater disposal and will increase the potential for disease transmission via this route by either breakdowns in waste treatment operations or improper disposal of such wastes. Development of increasingly marginal water supplies will require additional vigilance by water works personnel and all levels of health department personnel to prevent increased disease outbreaks from this source.

Vector-borne Diseases

The most significant vector-diseases are viral encephalitis (both the St. Louis and Western equine types), malaria, and bubonic plague. There are occasional cases of Rocky Mountain Spotted Fever, Tularemia leptospirosis, and endemic (murine) typhus fever. The number of cases in Arizona from 1965 through 1968 are shown in Table 55. Cases of diseases outside of Arizona are mentioned if they were known to have occured in the Lower Colorado Region. The six cases of bubonic plague near Gallup, New Mexico, were among Indian children on a reservation and is the largest single outbreak of plague in the United States since 1924.

Table 55 - VECTOR-BORNE DISEASE IN ARIZONA
1965 - 1968

Disease	Number of Cases Total	Lab Confirmed	Comments
Encephalitis	52	6	13 deaths
St. Louis		5	
Western Equine		1	
Malaria	10	--	Some cases appear to have been transmitted locally
Bubonic Plague	2	2	6 confirmed cases near Gallup, New Mexico in 1965
Rocky Mountain Spotted Fever	1	1	
Tularemia	1	1	
Typhus Fever (Endemic)	1	1	
Leptospirosis	1	1	

DRINKING WATER SUPPLIES

An estimated 1,500,000 (85 percent) of the population of the Region were served by public water systems in 1965. Approximately 25 percent (360,000) of this number used surface water sources for all or part of their supply. The remainder of the municipal systems utilized springs or wells as a source. It is a fairly safe assumption that the population not served by public water systems obtained its water from underground sources.

The degree of treatment given to the various surface water varies from a minimum of disinfection to complete conventional treatment. Predictably, the degree of treatment is low for the well supplies with the majority of the systems receiving no treatment -- not even simple disinfection. This is a common practice in the Western United States.

Status of Municipal Water Supplies

The total population receiving untreated water in the Region amounts to 865,000. This includes the estimated 640,000 served by untreated municipal systems as well as those individuals using non-municipal sources. The U. S. Public Health Service recognized the acceptability of this practice under the conditions that the wells are properly constructed; the groundwater is not subject to any possibility of contamination; and the waters continuously meet the requirements of the 1962 Drinking Water Standards. Realizing the difficulty of achieving the latter, there are strong grounds for recommending that all municipal water supplies should be receiving disinfection -- even those utilizing well waters that, to date, have proven adequate without treatment. Of particular concern is the practice of expanding municipalities taking over abandoned irrigation wells for a source of water supply. These wells are seldom constructed to the same sanitary standards as those for public water supplies and the records of well construction are inadequate to assess their acceptability when the time for take over occurs.

Chemical quality of the waters delivered by the municipal systems is quite varied and to a great degree unknown. Variations in dissolved solids, for example, range from around 100 mg/l for portions of the Flagstaff system to over 1500 mg/l for some of the well systems. The unknown is in those heavy metals having mandatory rejection levels in the 1962 Drinking Water Standards. See Tables 56 and 57. The drinking water supplies of the Region have generally not been analyzed for these substances. It is known, however, that many systems deliver waters that exceed the limits for nitrate and fluoride. Phoenix, for example, has several wells that produce water having nitrate concentrations in excess of 100 mg/l. A few localized problems exist where systems are high in toxic materials such as arsenic and hexavalent chromium. While some of the systems are high in fluoride, the majority of the populace are served water deficient in fluoride from the standpoint of prevention of dental caries in children.

Surveillance of water supplies is done principally by the health departments of the respective states. Unfortunately, these agencies are unable to give adequate attention to this matter. They are handicapped by lack of funds, number of trained engineers and other support personnel and facilities. The lack shows itself in all aspects of water supply surveillance, from too infrequent engineering surveys to lack of adequate bacteriological and chemical testing facilities. The lack of complete chemical data has already been noted.

Table 56 - PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS

Elements or Group	Recommended Limit of 1962 PHS Drinking Water 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/l 3/
Strontium	10 pc/l 3/
Gross beta	1,000 pc/l 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/l = picocurie per liter.
3/ These have been adopted on an interim basis since 1962 and do not appear in the 1962 Standards.

Table 57 - SUGGESTED PESTICIDE STANDARDS IN DRINKING WATER 1/

Pesticide	Maximum permissible concentration, mg/l 2/
Endrin	0.001
Aldrin	0.017
Dieldrin	0.017
Lindane	0.056
Toxaphene	0.005
Heptachlor	0.018
Heptachlor epoxide	0.018
DDT	0.042
Chlordane	0.003
Methoxychlor	0.035
Total organophosphorous and carbamate compounds 3/	0.1
2,4,5-TP (individual limits = 0.1 mg/l; Sum of)	
2,4,5-T (any combination of chlorinate phenoxy) 4/	
2,4-D (aklyl pesticides = 0.1 mg/l)	

1/ These standards have been adopted on an interim basis since 1962 and do not appear in the 1962 Public Health Service Drinking Water Standards.

2/ For long term exposure.

3/ Expressed in terms of parathion equivalent cholinesterase inhibition.

4/ Short period limit only: 2 mg/l for 3 days, no more than once or twice a year.

The breakdown in bacteriological testing is in getting the samples to the laboratory. It is necessary to mail samples to the state health department laboratories. This frequently brings about delays in excess of two days between sample collection and examination. "Standard Methods for the Examination of Water and Wastewater" recommends that "the time elapsing between collection and examination should in no case exceed 30 hours."

Summarized, the present water supply needs are disinfection of all public water supplies; increased chemical surveillance of the water supplies; increased engineering surveillance of the water systems; improved bacteriological examination of the water systems; and, in many instances, improved chemical quality in the raw water.

Future Problems

Perhaps the greatest problem to be faced in the Region in relation to public water supplies is related to the chemical quality of the raw waters available for the municipalities. At present a large portion of the population is drinking water that would be viewed with distaste, if not declared nonpotable, in many portions of the United States. With the population of the Region expected to triple by 2020, the problems of delivering adequate quality water will be even more difficult. To minimize this problem, domestic water supplies should be provided from the best existing high quality waters. Advanced treatment techniques should also be planned for those systems that presently fail, or will in the future fail, to meet the Public Health Service Drinking Water Standards.

The practice of using groundwater without disinfection places a great deal of importance on water quality control programs. Even with disinfection of public systems, the individual private systems are difficult to treat and can best be protected by proper control of the groundwater quality. Adequate licensing and training of well drillers must be included in future programs to insure proper well construction in all areas.

Protection of surface waters for drinking water purposes requires close surveillance and control over all aspects of water quality -- physical, chemical, radiochemical and organic. The need for stronger state programs in the surveillance of water supplies has already been mentioned. The need for closer monitoring in raw and/or finished water quality is also indicated. Present monitoring is woefully inadequate for any of the biocides and the trace metals of the Drinking Water Standards.

In addition to better monitoring programs, emergency procedures should be developed to report accidental contamination of existing or future surface water conveyance systems. These procedures are uncertain at best at the present. Operation and maintenance plans of these conveyance systems should also be reviewed to prevent unnecessary contamination of the water with biocides. Specifically, weed control on canal banks by use of herbicides should be done only after consultation with the appropriate State Health Departments and the water utilities using the canals as a source of raw water.

The importance of adequate surveillance of water systems by the health department cannot be overstated. This covers all aspects of water supply operation, review of plans, etc., for new construction, day-to-day advice and consultation, as well as provision of laboratory services. That this is already a problem has been previously mentioned. Without action it will continue to be a problem. Federal, state and local support to realize an effective program is urgently needed.

DISEASE VECTOR CONTROL

Present Status

Thirty-seven species of mosquitoes have been recorded in Arizona, including the vectors for all the common mosquito-borne diseases. Mosquito problems within the Region are related to the management of water resources. Irrigation practices are the major problem. Numerous ponds and other small impoundments account for significant mosquito production, while the large impoundments are often situated and managed to minimize mosquito production. Approximately one-half of the sewage oxidation lagoons in Arizona were producing mosquitoes at the time of the last state-wide survey (1960).

Bubonic plague in humans occurs within the Region. This disease is endemic in the wild rodent population and is usually obtained from contacts with an infected rodent or its fleas. Since domestic rats can become infected from wild rodents, the possibility of plague transmission to man would increase if the Region's relatively small rat population increased.

Vector control programs vary widely between states. The New Mexico State Health Department has a well staffed vector control section that provides strong leadership to local programs. Arizona does not do routine work at the state level and there is no enabling legislation for the creation and operation of mosquito abatement districts. Some communities have limited vector control programs. Both Nevada and Utah have enabling legislation for mosquito abatement districts, but there are no districts located within the Lower Colorado Region.

Future Conditions

Water resource development will increase the potential for mosquito breeding around reservoirs, canals, and irrigated fields. The projected increase in population and recreational activity will bring more persons in proximity with potential mosquito breeding areas. Furthermore, there is an increased possibility that diseases will be brought into an area as the population becomes larger and more mobile. Also, it is probable that restrictions on the use of insecticides will be greater than at the present time. It is important that adequate attention be given to vector control during project design and construction phases because the most effective means of mosquito control is by elimination of breeding areas. There is a definite need for more extensive vector control programs at the state and local level and for the existence of mosquito abatement districts in some areas. Future water resources development could cause an increase in the domestic rat population directly by providing moisture over a greater area, and indirectly by human activity from the wastes which provide them ample support. The rat problem can best be handled by improved solid waste handling and disposal and other environmental sanitation practices such as rat proofing of buildings.

ENVIRONMENTAL HEALTH ANALYSIS

Drinking water supplies and vector control are directly, and obviously, connected to water resources development. There are, however, other factors affecting health also directly related but in less obvious fashion. These factors include recreational development, solid waste disposal, air pollution control and radiological health protection. This section considers these aspects of water resources and related land development.

Recreation

Recreational activities may be separated into the two broadly defined areas of "urban" and "out-of doors." Urban recreation relates directly to health in terms of mental well-being but only indirectly in terms of water resources development. This relationship is in the area of land use in providing necessary space for close-in parks and golf courses, etc. Land has not been a limiting factor for this use in the Lower Colorado Region to date and with proper planning on the local level should not be one for the duration of the study. "Out-of doors" recreation relates to health in many ways and is covered in more detail below.

Water contact recreation (swimming, water skiing, etc.) constitutes an important use of the main stem of the Lower Colorado River and of the other sub-basins where sufficient water is available to pursue these activities. Bacteriological quality is the important parameter for these water uses. With the exception of a few localized areas, the waters are generally of sufficiently high quality to permit this use. Water quality standards prepared by the states include plans to maintain the existing high bacteriological quality of the surface waters and to improve those few areas which are poor at present. If these standards are followed, and there is no reason to expect otherwise, the bacteriological quality of the waters will be adequate for water contact recreation for the study period.

Camping is also an important recreational activity. This activity takes place at a myriad of private and public camping areas throughout the various sub-basins. These camping areas are in many respects very similar to small cities and face the same problems of water supply, liquid and solid waste disposal, and frequently air pollution that are experienced by permanent cities. With the exception of water supply, the problems faced by the camping areas in this Region are very similar to others having high recreational use.

The water supply problem in recreational areas is aggravated by the lack of good quality water for potable uses. The problem is in maintaining treatment facilities in camping areas. The small size of many of the areas and the scattered nature of them make operation and maintenance of treatment facilities quite difficult. This coupled with the initial expense of installation has limited the development of proper facilities. That they are needed is evident by the bacteriological records of these systems. Except for the largest and best maintained of the parks and camp areas, bacteriological data of the Arizona State Department of Health indicate that only a few of the general campground water systems in Arizona meet the requirements of the U. S. Public Health Service Drinking Water Standards. Additional pressures of an increased population will aggravate this situation.

Solid Wastes

Problems related to solid waste disposal may also be separated into the broadly defined categories of urban and rural. Nationally, the urban problem has received most of the attention but the problem of disposing of waste agricultural solids is also very important. The following relates both of these to water and related land resource development in the Lower Colorado Region.

It is estimated that a total of 2,000,000 tons of household, commercial and municipal solid wastes were generated in the Region in 1965. The basic method of disposal of these wastes is to the land, frequently in an uncontrolled and unsanitary manner. Proper control of these wastes are necessary to eliminate the health hazards created by these practices and to eliminate existing and potential surface and ground water contamination. This control may be obtained by several methods but the two most common practices to date are by land disposal and/or incineration.

The biggest problems to be faced in this area is that of land allocation in the three major population centers -- Clark County, Nevada, and Maricopa and Pima Counties, Arizona -- if land disposal of these wastes is to be continued. Table 58 is a presentation of the estimated land area necessary for solid waste disposal in 1965, 1980, 2000, and 2020.

Table 58 - ESTIMATED ACREAGE REQUIRED FOR LAND DISPOSAL OF SOLID WASTES 1/

	Subregion -- Acres/Year2/			Region		
Year	Lower Main Stem	Little Colorado	Gila	Acres Year	Rate Incr. Since 1965	Total Acres Since 1965
1965	76	27	309	412	--	--
1980	151	49	516	716	304	8,460
2000	380	79	1,079	1,540	1,128	31,020
2020	836	124	2,200	3,160	2,748	78,020

1/ Household, municipal, and commercial solid wastes only.
2/ Assumes 935 pounds/cubic yard of compacted refuse and 7 feet depth of sanitary landfill.

Alternative disposal methods are by composting or incineration. Composting has proven to be economically infeasible in the United States for production of fertilizer, but it might be investigated in this region. A more attractive disposal method may be by incineration with the use of the waste heat for power generation. This will result in consumptive water use due to cooling water and perhaps air pollution control equipment. Incineration without power production may also cause consumptive use of water in pollution control equipment.

Solid wastes from agricultural and industrial sources are not included in the metropolitan totals given above. These wastes have all the potential health problems that are associated with the typical municipal solid wastes, however, and must be considered. The problems may also be much more difficult to solve as the agricultural wastes are distributed over much larger areas than the typical large city. Although numbers are not available to precisely define the volume of this waste, national averages indicate that industrial and agricultural wastes, crop residues, and animal wastes are about 13 times the municipal wastes. In rough figures this amounts to a total of 26,000,000 tons of agricultural and industrial solid waste in 1965 with projected amounts of 50,000,000 tons and 500,000,000 tons in the year 1980 and 2020 respectively.

Radiological Health

The ingestion of radionuclides, either in water or in food, has obvious health implications. Limits have been set by the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements. Routine monitoring of water, air, and milk is conducted to insure that these limits are not being exceeded.

Hazards that are particularly applicable to water resources development are those associated with "Plowshare" projects, nuclear power development and water pollution from mine tailings. The Plowshare Program was undertaken to explore the potential for peaceful uses of atomic energy. There have been several trial projects but none to date in the Lower Colorado Region. A project that has been discussed is the use of a nuclear device for creating a permeable zone for ground water recharge in southern Arizona. The status of the project is uncertain at present but if developed there should be only minimal risks from the health standpoint. Testing by the Atomic Energy Commission and the Public Health Service for such a project is quite extensive and almost precludes any accidental human exposure to excess radiation. Health factors related to radioactivity from nuclear power reactors have been in three areas:

"high level" reactor wastes, "low level" cooling water wastes, and accidental gaseous wastes. Modern reactor design has all but eliminated these problems with the exception of the accidental release of "high level" wastes during shipment and processing. Since nuclear power is considered for development, safety procedures should be included for emergency actions to be taken in the event accidental releases to the environment should occur.

Water pollution from uranium mine tailings has been encountered in the Upper Colorado Region but is not a problem to date in the Lower Colorado Region. It is surmised that should such mining activities be undertaken at some future date, the lessons from the Upper Colorado Region would be applied and this problem avoided.

Other radiological factors not included in the above are uses of radioisotopes as tracers in hydrologic studies, medical research, and industries; nuclear fuel fabrication or recovery operations; and other specific applications. Any one of these matters must be considered on its own merits and as none of these activities are definitely planned at the present, it is not feasible to speculate on their effects on the basin.

Air Pollution

The States of the Lower Colorado Region either have planned or ongoing air pollution control programs. It is anticipated that these programs, in cooperation with the Air Quality Office of the Environmental Protection Agency will be active in reviewing all water resources and related land developments affecting the quality of the Region's air resource. Aside from the increase in air pollution problems in the major metropolitan areas caused by the influx of people and industry which water resource development stimulate, typical problems would be from thermal power production, agricultural burning, and large water-based industries.

The development of thermal power has perhaps the most direct relation to water resources development. With the provision of proper air pollution control equipment, air pollution problems from this source may be minimized. The fact remains, however, that even under the most controlled conditions some residual pollutants remain to be disposed of to the atmosphere. The proper siting of these plants to minimize the effect of this discharge is quite important. This, coupled with the siting problems being experienced in other areas, makes early designation of land resources for the location of thermal power generating facilities quite important.

Agricultural burning has yet to become a problem in the Region. Any crop change that will lead to burning as a means of disposal of agricultural solids must be considered carefully to see that it is compatible with regional air pollution control plans.

OBE·ERS ADDENDUM

OBE-ERS ADDENDUM

The Modified OBE-ERS projections were used throughout the preceding portions of this appendix. They are based upon revisions of the OBE-ERS projections furnished to the Region by the Water Resources Council.

Similar to the Modified OBE-ERS data, the OBE-ERS projections were converted to land and water requirements by the responsible Work Groups. Supporting information is contained in the proper appendixes.

Comparative summaries of consumptive-use and withdrawal requirements are presented in the Water Resources Appendix. The areas of major differences are irrigated acreage and population; yet the resulting difference in terms of net water use is only 0.5 maf, the OBE-ERS projections requiring about 10 percent less water.

As the OBE-ERS projections indicate a lesser population, and consequently lesser quality and pollution problems, and as the differences between the two projections are small, the means for meeting needs and the costs discussed in this appendix will fully satisfy the OBE-ERS requirements.

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