Water for Nevada

Special Planning Report

WATER SUPPLY FOR THE FUTURE IN SOUTHERN NEVADA

MONTGOMERY ENGINEERS OF NEVADA
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WILLIAM H. BLACKMER
PRESIDENT

December 31, 1970

Mr. Roland D. Westergard
Nevada State Engineer
Carson City, Nevada 89701

Dear Mr. Westergard:

We are pleased to submit the accompanying report entitled "Water Supply for the Future of Southern Nevada." This report describes several alternative plans for alleviating a projected water shortage in southern Nevada near the turn of the century. The plans include importing water from within the state, importing water from outside the state, reducing water use, dispersing population, and limiting population growth.

Unlike most studies of this type, we have not made a recommendation as to which alternative should be selected in the event the projected water shortage occurs. Each of the alternatives involves the Las Vegas Community and, on some projects, outlying communities. Each alternative has negative and positive aspects, the values of which are intangible. Thus, the final selection of alternatives is not entirely an engineering or economic consideration, but rather a matter of how the selected plan affects the people involved. It is for this reason that one of our recommendations emphasizes the need for wide distribution of the report so that a broad spectrum of opinion may be obtained before action is taken to implement any segment of the report.

During the preparation of this report we had the pleasure of working with you and several members of your staff, all of whom were especially cooperative. Also we were the beneficiaries of considerable assistance from numerous public and private organizations. All of this valuable aid and support is greatfully acknowledged. The report was prepared by Edward L. Kostjal, Fred K. Duren, and Dr. A. W. Morgner, consulting economist, under the direction of William H. Blackmer and was reviewed by William J. Carroll.

We have thoroughly enjoyed preparing this report, a portion of the State Water Plan. We wish to thank you for the opportunity of having served the State in this regard.

Very truly yours,

W H Blackmer

W. H. Blackmer

WATER

FOR NEVADA

Prepared by the State Engineer's Office
JANUARY 1971

ELMO J. DeRICCO
Director

STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
DIVISION OF WATER RESOURCES
201 South Fall Street, Carson City, Nevada 89701

ROLAND D. WESTERGARD
State Engineer

In reply refer to
No.

Address All Communications to the State Engineer, Division of Water Resources

TO THE CITIZENS OF THE STATE OF NEVADA:

This Report is one of a series of Planning Reports to be prepared for the people of Nevada to assist them in following and understanding the development of the State Water Plan.

One of the Principles we have established for planning the use of the water and related land resources of Nevada is that early attention will be given to meeting the needs of those areas of the State which are presently experiencing water shortages and those areas which may be water deficient in the near future.

Following this Principle, a consulting engineering firm, Montgomery Engineers of Nevada, was chosen to study and evaluate alternative ways to meet the potential water needs in Southern Nevada over and above those which can be met with the importation of Nevada's allocation of mainstream water from the Colorado River through the Southern Nevada Water Project.

Five alternatives were considered and are described briefly as follows:

1. Importation of Water from sources within Nevada.
2. Importation of Water from sources outside Nevada including desalinization of ocean water and exchange with the Metropolitan Water District.
3. Alleviating water needs through the economization of water.
4. Population Redistribution.
5. Limiting Population Growth.

While this Planning Report deals with future water needs in Southern Nevada the concepts and effects of the alternate courses of action considered are applicable throughout the State.

The Report will be widely distributed for review and public meetings will be held with agencies and groups to discuss the Study. It is our opinion that the Report and such meetings will provide the type of information needed to facilitate the decision making process.

Respectfully,

Roland D. Westergard
State Engineer

WATER SUPPLY FOR THE FUTURE IN SOUTHERN NEVADA

Special Planning Report

SUMMARY

1. The Las Vegas Metropolitan Subarea is predicted to have a population of between 1,100,000 and 1,300,000 in the year 2020.

2. The water requirements for Las Vegas Metropolitan Subarea are expected to exceed supply (ground water, Lake Mead water, and reclaimed waste water) by 28 percent to 39 percent in the year 2020 respectively for the low and high population projections.

3. Other subareas near Las Vegas have been investigated in order to ascertain whether the projected deficiency is widespread and whether these subareas might have water available for export. In determining whether water would be available for export, an amount of water equivalent to that contained in the upper 100 feet of the ground water basin was considered to be available for mining. The results for the nine subareas studied follows:

Subarea with Water Deficiency	Subareas with Water Balance	Subareas with Water Available for Export
Las Vegas Metropolitan	Fort Mojave	Virgin Valley
	LMNRA	Pahrump Valley
	Moapa Valley	Amargosa Desert
		Railroad Valley
		Pahranagat Valley

4. Of the five subareas with water available for export, all but the Virgin Valley have enough water resources to supply Las Vegas' needs through the year 2020, if an amount of ground water equivalent to storage in the upper 100 feet of saturated material is considered available for export to Las Vegas. The water is of acceptable quality except for high fluorides in Amargosa Desert and very high dissolved solids in the Virgin River.

5. The estimated cost of importing water from outside Nevada is as follows:

Plan**	Unit Cost Production $/Ac.Ft.	Unit Cost Production & Distribution $/Ac.Ft.*
Snake-Colorado Project	175	240
Modified Snake-Colorado Project	190	255
Desalinization	200	265

* Cost to ultimate consumer
** All plans based on utilization of Lake Mead as a terminal reservoir.

6. Instead of constructing expensive facilities for conveying water to Las Vegas, it is believed feasible to reduce water consumption in Las Vegas so that a water shortage would not occur. An estimated increase in water rates of about 100 percent is believed to be sufficient to achieve this.

7. Redistribution of population to subareas with water surpluses may be possible if enough incentives are established by governing bodies. However, the cost of transporting workers between these outlying subareas and Las Vegas greatly exceeds the cost of constructing aqueduct systems.

8. Elimination of the water problem faced by Nevada could result if projected population growth failed to occur; however it is difficult to conceive of a deterrent to population growth which would not adversely affect present residents of Nevada.

9. The estimated cost, based on 1970 construction costs and 7 percent interest, of water from the five subareas of surplus conveyed to Las Vegas is as follows:

SUMMARY

Project	High Population Projection			Low Population Projection		
	Capital Cost	Unit Cost Delivered	Unit Cost Delivered & Distributed*	Capital Cost	Unit Cost Delivered	Unit Cost Delivered & Distributed*
Pahrump Valley	$237 million	$186/ac.ft	$248/ac.ft	$185 million	$168/ac.ft.	$230/ac.ft
Amargosa Desert	$295 million	$270/ac.ft	332/ac.ft	$227 million	$225/ac.ft.	287/ac.ft
Railroad Valley	$474 million	$252/ac.ft.	330/ac.ft	$372 million	$268/ac.ft.	314/ac.ft
Pahranagat Valley	$246 million	$214/ac.ft.	276/ac.ft	$192 million	$178/ac.ft.	240/ac.ft
Virgin Valley	---***	$ 63/ac.ft.**	125/ac.ft	---***	$ 63/ac.ft.**	125/ac.ft

* Cost to ultimate consumer

** Estimated unit cost based on using Lake Mead for storage, blending and conveyance.

*** The capital cost of the Virgin River project would depend upon the amount of upstream use.

RECOMMENDATIONS

1. A continuing educational program should be initiated immediately to inform residents of the Las Vegas Metropolitan Subarea of the need to conserve water. The intent of such a program would be to achieve a pattern of voluntary reduction in use so that the need to import water before 2020 would be obviated.

2. A tri-state compact should be consummated with Utah and Arizona concerning rights to the Virgin River. Negotiations should be continued with the U.S. Bureau of Reclamation to obtain credit for flows, both surface and underground, entering Lake Mead from the Virgin River.

3. Nevada should join with other southwestern states to formulate a plan to import water from outside this arid region. The target date for deliveries should be not later than 2020.

4. Nevada should continue to work with other states along the Colorado River to reduce the river's degradation.

5. If development, in an area warrants further investigation of its ground water basin, or if a basin is seriously being considered as a source for export of ground water, then it is recommended that it be investigated in much more detail than has been done to date in order to more clearly define its water resource and the inter relationship of this resource with other basins.

6. This report should be widely distributed for comment. After receiving a broad spectrum views concerning it, the most promising plans to alleviate the projected water shortage in Las Vegas should be investigated further.

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PART 1

NARRATIVE SUMMARY

Paradoxically, at the time when southern Nevada is anticipating its first deliveries of water from the Southern Nevada Water Project (SNWP) concerned water administrators in the Division of Water Resources are looking ahead to the turn of the century when a water shortage may again occur. This report examines the water requirements and possible sources of a supplemental supply in the period from 1993 to 2020. The first date is the earliest at which a problem is expected. The second is the latest assumed time when additional water will become available from outside Nevada and the problem will no longer exist.

The purpose of this study is to make an overview of the logical alternatives open to water managers of Nevada, estimate the cost of each alternative, and try to forecast the effects of implementing each plan. Needless to say, this study is of reconnaissance grade, but it does delineate the more promising plans for further study.

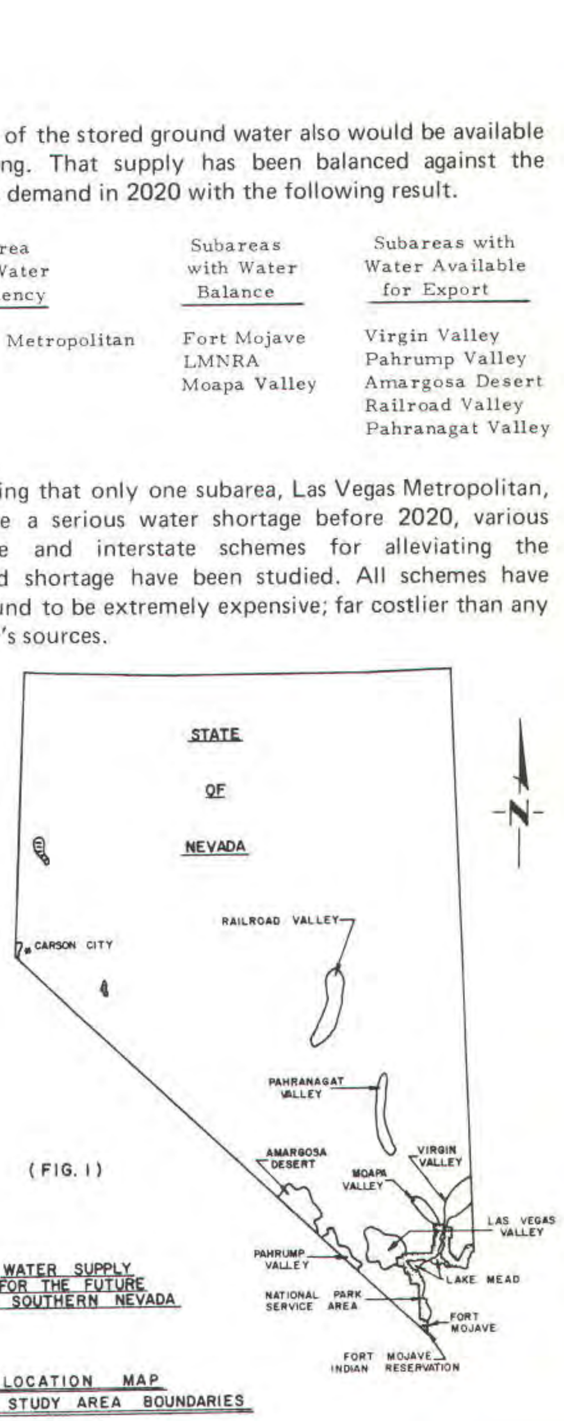
This report has been divided into two parts so that the casual reader as well as one who is technically oriented may each have a readable and complete account of the findings of the study. Part 1 minimizes details and technical jargon, while Part 2 contains necessary backup material to make the findings understandable and reproducible.

The study area is the populated or soon-to-be populated portion of southern Nevada and five possible areas having a substantial water resource. The study area has been divided into nine subareas as shown on Figure 1. Many small communities have been left out of the study, because it is believed they will not affect its results and to investigate the entire southern Nevada water situation is beyond the scope of the report.

To quantify the extent of the problem, population projections have been made for each subarea. From the population predictions, water requirements for each subarea have been estimated for the year 2020. These water requirements are based on a supply of potable water being available at reasonable prices. Each subarea has some water supply. For the purposes of this study, it has been assumed that the equivalent amount of water contained in the upper 100 feet of the stored ground water also would be available for mining. That supply has been balanced against the subarea's demand in 2020 with the following result.

Subarea with Water Deficiency	Subareas with Water Balance	Subareas with Water Available for Export
Las Vegas Metropolitan	Fort Mojave	Virgin Valley
	LMNRA	Pahrump Valley
	Moapa Valley	Amargosa Desert
		Railroad Valley
		Pahranagat Valley

Concluding that only one subarea, Las Vegas Metropolitan, will have a serious water shortage before 2020, various intrastate and interstate schemes for alleviating the projected shortage have been studied. All schemes have been found to be extremely expensive; far costlier than any of today's sources.



(FIG. 1)

LOCATION MAP
SHOWING STUDY AREA BOUNDARIES

NARRATIVE SUMMARY

In addition to the engineering studies, economic investigations have been made of the possibility of reducing demand, dispersing population or limiting population growth, in efforts to eliminate the shortage.

If we start the 21st century with a water shortage in Las Vegas, it is simply because of people--too many of them. Trying to predict population growth has always been an onerous task as the recent census so capably demonstrated. But even the census bureau has its share of problems. When it released the 1970 figures, the census bureau also released new predictions for United States population in 2000. The new predictions were from 6 percent to 11 percent lower than those previously predicted by the bureau.

Why the decrease? The principal reason is that the birthrate has slumped from an average of 3.24 children per woman of child bearing age in the period from 1945 to 1965 to today's rate of 2.45. This little-noticed trend could affect all long-term population projections. It could materially affect the water demand in Las Vegas. The study, however, has been completed on the basis of no drastic downturn in the rate of population growth.

It has been assumed that reclaimed waste water, to the extent of 30 percent of total water demand of the Las Vegas Metropolitan subarea would be available for use by the time it is needed. Whether the waste water is made available as a credit after discharge into the mainstem of the Colorado River, as a potable water after receiving extensive treatment, or as an increased ground water resource after being used to recharge the ground water basin is immaterial from the standpoint of this study as long as it is cheaper than the importation plans.

A description of each subarea along with its predicted population in 2020, its water requirements, and its water resource is given in the following paragraphs.

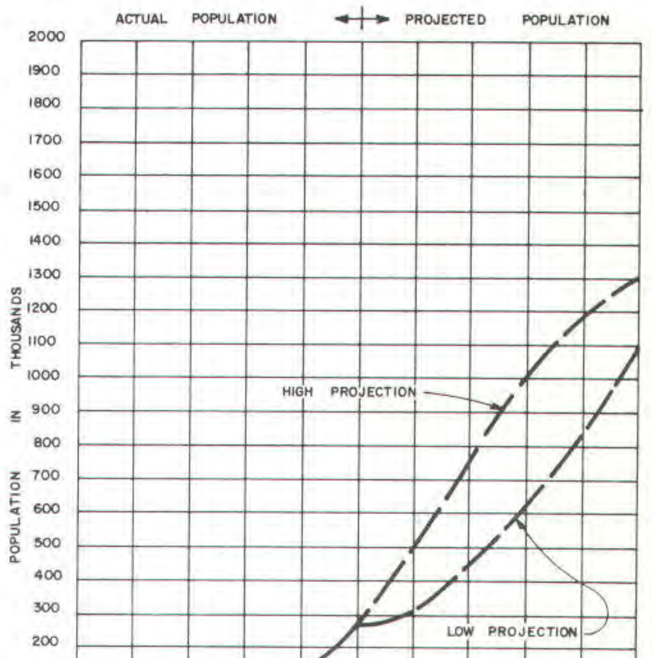
DESCRIPTION OF STUDY AREA

Las Vegas Metropolitan Subarea. The Las Vegas Metropolitan subarea is located in southern Nevada and includes the cities of Las Vegas, North Las Vegas, Boulder City, and Henderson. On the western boundary of the subarea are the Spring Mountains, while along the eastern side are the Las Vegas and Sheep Ranges and Frenchman Mountain. The northern border is formed by the Desert, Pintwater, and Spotted Ranges, and the McCullough Range and River Mountains form the southern border.

The climate of the subarea is arid, the average annual precipitation being approximately 4 inches. The summers are long and commonly have temperatures of 100 degrees or more, while the winters are short and mild. No perennial streams of any significance cross the basin. The Las Vegas Valley is drained to Lake Mead by Las Vegas Wash which carries a perennial flow consisting mostly of waste water.

Latest population figures indicate that the subarea supports approximately 265,000 residents. The bulk of this population is centered in Las Vegas and North Las Vegas. During the last 20 years the subarea has experienced one of the fastest growth rates in the nation. The 1950 population of about 48,000 has risen more than 400 percent to reach its present level. Two industries, the gaming-entertainment industry and the military-nuclear research-heavy industry, have been the primary factors contributing to this growth. The tourist related industry is the most important, accounting for a direct employment of about 34,000. The other industries involve approximately 16,000 employees.

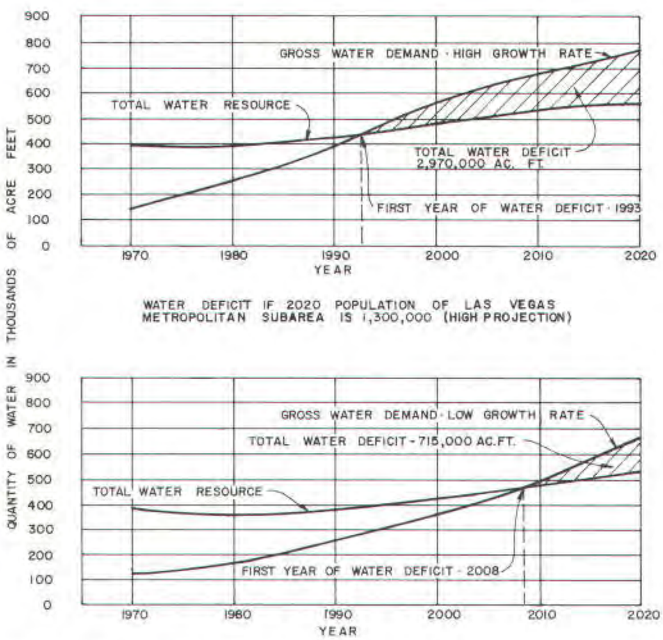
Water requirements for the Las Vegas Metropolitan subarea have been determined on the basis of the population estimates shown in Figure 2. These water requirements do not include water for any new major power generation installation in the study area. These water requirements,



(FIG. 2)

POPULATION PROJECTIONS IN LAS VEGAS METROPOLITAN SUBAREA shown graphically in Figure 3, indicate that there will be a deficiency of from 131,000 acre feet to 211,000 acre feet per year, for the low and high population projections respectively, in the subarea by 2020. These deficiencies assume complete utilization of the Southern Nevada Water Project (SNWP) and reclaimed waste water.

Withdrawals from the Las Vegas Valley ground water basin after the completion of the SNWP and revocation of temporary permits has been assumed to be 50,000 acre feet per year. Diversions from Lake Mead are expected to be about 281,000 acre feet per year. Together with reclaimed waste water, these water sources account for the water resource shown in Figure 3.



(FIG. II-2) WATER DEFICIT IF 2020 POPULATION OF LAS VEGAS METROPOLITAN SUBAREA IS 1,100,000 (LOW PROJECTION)

COMPONENTS OF TOTAL WATER RESOURCE

1. Withdrawal from Las Vegas Ground-Water Basin 50,000 Ac. Ft./Yr.
2. Nevada's entitlement of Colorado River water which is available for use in Las Vegas Metropolitan Subarea is approximately 281,000 Ac. Ft./Yr.
3. Quantity of reclaimed water is 0.3 times the gross water demand.

GROSS WATER DEMAND BASED ON:

1. Present daily per capita use of 475 gallons
2. Per capita water use will increase at the rate of 2.5 percent each 10 year period.

Fort Mojave Subarea The Fort Mojave subarea is located at the extreme southern tip of Nevada approximately 100 miles south and slightly east of Las Vegas. On the east, the subarea is bordered by the Colorado River, while north is the Lake Mead National Recreation Area. The land in the subarea is undeveloped desert with some hills and gullies. Vegetation is sparse in this arid land. As is usual for southern Nevada, the average annual rainfall is low and long, hot summers and short, mild winters are common.

The population of this subarea is almost 100. The Southern California Edison Company recently completed construction of a steam power generating station in the subarea. Land developers have plans to develop the subarea as a second home or retirement place with some modest-size casinos and hotels complementing the usual commerical enterprises. The entire subarea is planned to be water oriented as full use of the Colorado River frontage is anticipated.

The future water requirements of this subarea depend primarily upon whether development materializes. If the developer's plans for the area become reality, then considerable water would be required. The Colorado River Commission of Nevada (CRC), has tentatively allotted 13,000 acre feet of water per year to four development firms which have plans for the subarea. In addition, the CRC has allotted a variable amount to the Edison Company; 30,000 acre feet per year to 1985, a steadily declining amount varying between 30,000 in 1985 and 15,000 in 2000; 15,000 acre feet per year from 2000 to 2006; and nothing after 2006. The allocations for the developers from the mainstem of the Colorado River are sufficient to support an equivalent permanent population of about 50,000; a probable figure for the area by the year 2020. In addition to using water from the mainstem of the river, ground water may also be withdrawn for domestic use. Therefore no water shortage is foreseen for the Fort Mojave subarea.

Lake Mead Nation Recreation Area (LMNRA). The Lake Mead National Recreation Area is the subarea encompassing the shoreline of Lakes Mead and Mojave and a portion of the Colorado River running along the easterly boundary of the state. This subarea extends back from the shoreline a few miles and has a boundary that is highly irregular.

The vegetation is very sparse, as is characteristic for all of southern Nevada. Also, the climate is arid, with long, hot summers and short, mild winters. Total permanent population of the area is estimated to be only about 300 although 5.75 million visitor days were spent in the subarea during 1969.

The assumption has been made that the Nevada portion of the LMNRA, along with other federal users such as Indian reservations, will need in the future about 6,000 acre feet per year from the mainstem of the Colorado River. There are so many intangibles associated with the water requirements for the LMNRA that it is hazardous to predict whether a water shortage will occur by 2020. The large

NARRATIVE SUMMARY

proportion of transients consuming water, unquantified needs on federal lands and the varied type of water use all contribute to the difficulty in assessing the future water situation in this subarea. However, it seems that a balance between supply and demand may occur for the LMNRA and other federal users. Consequently, it has been assumed that the LMNRA is a subarea without a water surplus or deficiency.

Moapa Valley Subarea. The Moapa Valley subarea is located approximately 50 miles northeast of Las Vegas in the Muddy River drainage basin. Gentle-rolling hills and flat lands predominate in this subarea of moderate relief. The elevation varies only about 500 feet from a low of nearly 1200 feet. As is typical for the southern region of Nevada, the land is desert with sparse vegetation. Precipitation averages less than 5 inches a year, most of which occurs in short intense storms. The climate is characterized by long, hot summers and short, mild winters, which are common to all of southern Nevada.

This subarea is identical to numerous other undeveloped southern Nevada regions in its sparsity of population. Total population of the four primary towns, Moapa, Glendale, Logandale and Overton is about 2,200. Agriculture and tourism are the base industries. The subarea also serves as a bedroom community for a few workers employed in Las Vegas and at the Nevada Test Site.

Moapa Valley is supplied water from the Muddy River which is fed by numerous small springs. The springs collectively discharge water at an almost constant rate of 46.5 cubic feet per second (34,000 acre feet per year). While the top 100 feet of the ground water basin has 800,000 acre feet of water in storage, it is of poor quality.

It appears that the water resources available within this subarea will be sufficient for its needs through the year 2020. If the water now being utilized for agricultural use is diverted to municipal and industrial use, Moapa Valley could support a total population of 50,000 far more than the 20,000 considered to be the most probable population. The water would have to be treated to reduce the fluoride content before being used for domestic purposes. Excessive fluoride causes discoloration of teeth if it is persistently used.

Virgin Valley Subarea. The Virgin Valley subarea is located northeast of Las Vegas, approximately 80 miles distant. It includes the portion of Nevada along the lower Virgin River. The climate of this subarea is characterized by the usual southern Nevada long, hot summers and short, mild winters. Average annual precipitation is near 5 inches, accounting for the sparsity of vegetation.

Total population of the subarea is probably less than 1,100 with 700 residing in Mesquite and 300 in Bunkerville. Farming is the base industry. About 3,000 acres are currently under cultivation. There are also dairy and range cattle in the subarea. Highway 91 passes through Mesquite and tourist-related services are prevalent there.

The assumption has been made that this subarea is too far removed from Las Vegas to become an important commuter community, it is estimated that the population in 2020 will be about 10,000.

The domestic water requirement for that population will be about 4,500 acre feet per year. Even with the present agricultural water use of 13,000 acre feet per year added, the total water demand in 2020 falls short of the 123,000 acre feet per year expected to reach Lake Mead, as surface flow and ground water movement. If the proposed Dixie Project on the Upper Virgin River is constructed, the quantity of water reaching Lake Mead would be reduced to 60,000 acre feet per year.

Without very expensive storage and treatment, the Virgin River cannot be considered a good source of water for exportation to Las Vegas because of its irregular flow and very poor quality (very high dissolved solids which can impart taste to the water and act as a cathartic). Since the United States Supreme Court has held that the Lower Basin states are entitled to exclusive use of the tributaries of the Colorado River within each state, the possibility exists that an entitlement could be obtained for the surface and subsurface inflow to the mainstem of the Colorado River from the Virgin Valley. This combined outflow to Lake Mead has been estimated to be about 123,000 acre feet per year, two-thirds being surface water and one-third ground water. By claiming that the introduction of Virgin Valley water into Lake Mead creates an entitlement by the State to increase diversions of water from the mainstem of the Colorado River over and above the 300,000 acre feet per year apportioned to Nevada, the State might use Lake Mead as a conduit and divert the subject tributary water from the lake at any convenient location. The quality of water would be greatly improved by its being blended with Lake Mead water.

Pahrump Valley Subarea. The Pahrump Valley subarea is situated about 60 miles west of Las Vegas. The valley is approximately 42 miles in length trending northwest-southeast between the Spring Mountains on the east and the Nesting Spring, Nopah, and Kingston Ranges on the west. Pahrump Valley is a closed topographic basin since there is no outlet for streams to flow from the valley.

The topography of this subarea is typical of the basins in the Basin and Range Province. The valley is characterized

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VIRGIN RIVER COUNTRY – NEVADA

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PAHRUMP VALLEY – NEVADA FROM MT. CHARLESTON by flat to very gradual slopes. Very sparse vegetation is predominant in the valley. Precipitation in this arid basin is light. The average annual precipitation is a little over 3.5 inches. Large ranges in daily temperature are common. The climate is characterized by long, hot summers and short mild winters.

The basic industry in Pahrump Valley is agriculture. There are a very few service supporting activities. About 30 ranches encompassing a total of about 11,000 acres of cultivated farm land are situated in the valley. Total population of the subarea is presently about 1,200. The principal town is Pahrump, which serves chiefly as a bedroom community for workers at the Nevada Test Site.

Unless large-scale promotional efforts achieve spectacular growth in the valley, the anticipated population in 2020 is 10,000 with a domestic water requirement of 4,500 acre feet per year. Presently about 48,000 acre feet per year is being extracted from the ground water basin to irrigate 11,000 acres and supply domestic requirements. The annual recharge to the basin is about 22,000 acre feet. No additional permits to appropriate ground water for irrigation purposes are being issued in Pahrump Artesian Basin. Under certain conditions, permits to appropriate ground water are being issued for domestic, municipal, quasi-municipal, industrial, mining, and stock watering uses.

The volume of good quality ground-water storage in the top 100 feet is 6 million acre feet. Most of this could be exported to Las Vegas and used to satisfy the anticipated water shortage there. Curtailment of agriculture would result from this practice, but residential expansion could continue to take place.

Amargosa Desert Subarea. The Amargosa Desert is situated about 100 miles northwest of Las Vegas. This subarea extends in a southeasterly direction from Beatty for about 50 miles. Bordering the Amargosa Desert on the north are Bare Mountain and Yucca Mountain, while the eastern boundary is formed by the Specter and Resting Spring Ranges and the Spring Mountains. Along the western and southwestern boundaries are the Funeral Mountains and the Greenwater Range. Pahrump Valley is immediately southeast of this subarea.

The topography within this subarea is characteristically gentle along the valley floor. As is true for most of the arid areas of southern Nevada, the vegetation is very sparse. The average annual basin precipitation is only about 4 inches. Annual evaporation is very high--about 10 feet. The Amargosa River channel which originates in the mountains near Oasis Valley trends southeasterly across the desert floor toward Death Valley Junction, California. Normally, the channel is dry except for periods immediately following heavy rains.

The Ash Meadows area of the Amargosa Desert contains numerous springs. The total annual discharge from these springs is nearly 17,000 acre feet, of which a considerable amount is lost through **evapotranspiration**.

The principal town of this subarea is Beatty with a population of about 1,200. Lathrop Wells with a population of less than 100 is the only other Nevada town in the Amargosa Desert. Roadside businesses in the two towns along with a limited amount of agriculture forms the basic economy of the subarea. Most of the residents who are not connected with either farming or roadside business are employed at the Nevada Test Site.

If the population projections given in the report are attained, Amargosa Desert will have a population of about 5,000 in 2020. Past domestic and agricultural uses of water have not caused an appreciable mining of the ground-water basin.

The perennial yield has been estimated to be 24,000 acre feet per year and the amount of ground water in storage in the top 100 feet of saturated material to be 2.7 million acre feet. The ground water is high in fluorides but is otherwise acceptable for potable use.

It has been assumed that ground water in an amount equivalent to the upper 100 feet of ground water in storage would be available for export to Las Vegas. Once there the water could be blended in order to reduce the fluoride concentration. Irrigation water rights which would be adversely affected by export would have to be purchased if water were to be exported. Domestic development would not be affected by large-scale water exportations.

Ground-water lowering in the vicinity of Ash Meadows that might be associated with mining for exportation, could endanger the lives of the rare pupfish found in water holes at the southern tip of the subarea.

Railroad Valley Subarea. Railroad Valley is the subarea farthest from Las Vegas. This subarea is located approximately 175 miles north of Las Vegas. The 70 mile-long valley trends almost north-south. It is bordered on the east by the Quinn Canyon, Grant, and Horse Ranges and on the west by the Pancake Range. The vegetation of the valley is sparse as in the other basins of southern Nevada. Precipitation is also typical of the southern Nevada area as the average annual total is less than 10 inches. The climate is arid with hot summers and cool winters. Since this valley is at an elevation of about 5,000 feet, the winters are a little more severe than those of the other subareas which are lower.

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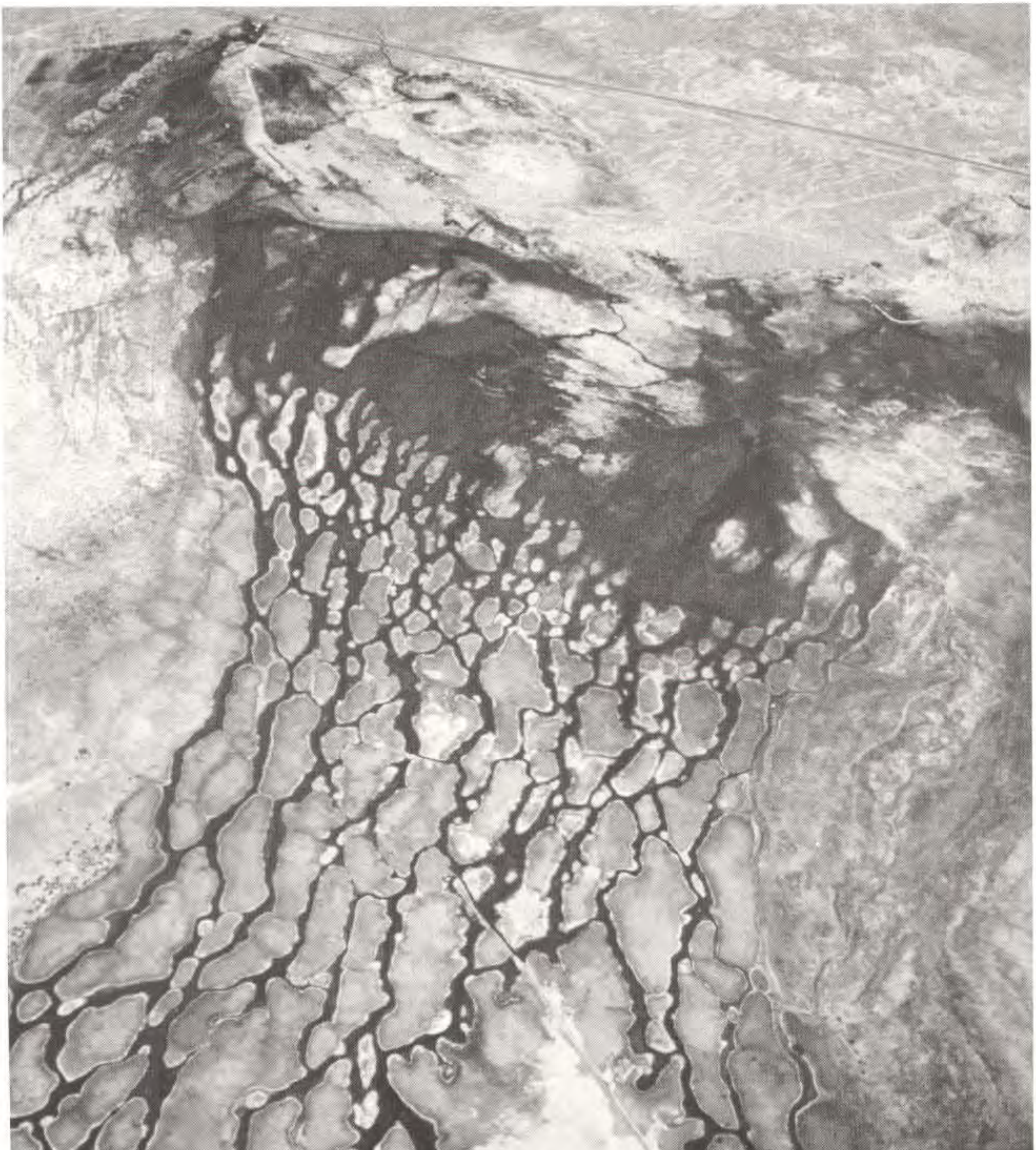
AMARGOSA DESERT – NEVADA



AERIAL – SPRINGS AT LOCKES – RAILROAD VALLEY – NEVADA

The present population of Railroad Valley is less than 100, consisting wholly of people on a few farms in the area. Currant is the one small community located in the valley.

No population growth is expected in the area in the future. Existing farms may continue; however, most likely no sizeable population increase above the present population is expected, unless federally-controlled lands are made easily available for development.

The Railroad Valley ground water basin is large and contains water of good quality. The volume stored, 7 million acre feet in the top 100 feet, is more than adequate to satisfy Las Vegas' needs past 2020. Exportation from Railroad Valley would affect residents of the subarea of origin the least of any intrastate plan.

Pahranagat Valley Subarea. The Pahranagat Valley subarea is situated about 90 miles north of Las Vegas. The valley trends north-south for about 30 miles. The northern boundary is formed by the junction with Pahroc Valley. The north end of the Sheep Mountains marks the southern boundary of the subarea. On the east the Hiko Range forms the boundary and on the west is the Pahranagat Range.

An arid climate is characteristic of Pahranagat Valley. The winters are cool while the summers are hot. A large range in daily and seasonal temperatures is common. Average annual precipitation is about 6.5 inches. Vegetation is sparse except for a green strip about a quarter of a mile wide down the middle of the valley.

Total population of the subarea is less than 500, of which 300 reside in Alamo. Ash Springs, Crystal Springs, and Hiko are three very small communities in the subarea north of Alamo. Farming is the economic base with about 6,000 irrigated acres. The non-farming population is generally engaged in work with the Nevada Highway Department or local service activity; some also work in Las Vegas and at the Nevada Test Site.

The water requirements of the valley are approximately 25,000 acre feet per year. The estimated increase in population to 2,500 in 2020 will not have much affect on the water requirements. With an annual recharge of 25,000 acre feet and 2.2 million acre feet in the top 100 feet of ground water storage, this valley is a likely candidate as an area of origin. If irrigation water rights are purchased and the ground water basin is used as a supplemental water supply for Las Vegas, two effects could materialize. The springs feeding the Muddy River could reduce their flow and the Pahranagat Lakes could become dry. The former would have an adverse effect on Moapa Valley. The latter would have a serious effect on the wildlife using these lakes.

ALTERNATIVE WATER SUPPLY PLANS

There have been eight alternative water supply plans considered in this study. Five of the plans import water to the Las Vegas subarea from areas within Nevada, and the other three alternatives bring water from out-of-state areas. Although the eight plans considered are not intended to be an all-inclusive list of the possible water supply alternatives for supplying additional water to southern Nevada, they are a representative sample of the most feasible alternatives. Each plan considered has been analyzed singly and not in combination with any other plan.

Intrastate Water Plans. Four of the five plans studied require pumpage of ground water from one of the following subareas: (1) Pahrump Valley, (2) Amargosa Desert, (3) Railroad Valley, and (4) Pahranagat Valley. In each plan it is proposed to transport ground water from the subarea by aqueduct to a reservoir near Las Vegas. From there, the water could be treated and conveyed by gravity to the Las Vegas Metropolitan subarea. The fifth plan involves the use of Virgin River outflow to Lake Mead. Water from that river would use Lake Mead for conveyance, blending, and storage.

All five plans have been designed for both the high and low population estimates. The analysis for each population estimate includes a paper layout of the physical components of the water collection and supply systems and an estimate of the cost of the facilities. The cost analyses have been done on the basis of a 7 percent interest rate on capital investment and 1970 construction costs. Reparations for obtaining water rights have been included as a capital cost. The amortization period (useful project life) varies for each of the plans.

It should be emphasized at this point that all of the intrastate water plans, except importation from Virgin Valley, are interim projects. Once the end of the useful project life has been reached, it has been assumed that the projects would cease to supply water to Las Vegas. For each of the plans, the useful life has been assumed to be the amount of time required to withdraw an amount of ground water equivalent to that contained in the upper 100 feet of saturated valley fill or 50 years, whichever is shorter.

The aqueducts have been sized to convey 120 percent of average annual demand for imported water in the year 2020 as far as the terminal reservoirs. This results in a design flow of 350 cubic feet per second for the high population projection and 216 cubic feet per second for the low projection. Downstream of the terminal reservoirs, the aqueducts have been sized to deliver 135 percent of average flow. The terminal reservoir has been determined to be either 11,000 acre feet or 14,000 acre feet in size in order

NARRATIVE SUMMARY

PAHRANAGAT VALLEY – NEVADA

to achieve the 135 percent delivery rate to the Las Vegas Metropolitan subarea.

Pahrump Valley. The first intrastate water supply alternative considered in this study involves extraction of ground water from Pahrump Valley and conveyance through more than 75 miles of aqueduct to a holding reservoir west of Las Vegas. This alternative would require two pumping stations to lift the water nearly 1,500 feet up to an 8.5 mile long tunnel in the Spring Mountains. Energy dissipators would be employed to dissipate over 1,700 feet of energy as the water would be conveyed down to the elevation of the terminal reservoir. Preliminary studies have shown that it would be less expensive to purchase power than to generate it as part of the project. More detailed studies may reverse this statement. The costs of the Pahrump Valley-Las Vegas aqueduct are tabulated in Table 1.

Amargosa Desert. The alternative plan for supplying the Las Vegas subarea with water from the Amargosa Desert involves a total transport distance of over 130 miles. A pumping station would be required to lift the water approximately 1,350 feet over the mountains. An open channel and pipeline aqueduct would carry the water from the well field in the Amargosa Desert to the holding reservoir, approximately 6 miles north of Nellis Air Force Base. Water from Amargosa would be blended with SNWP water to reduce fluoride concentrations. See Table 1 for the cost of the Amargosa plan.

Railroad Valley. The intrastate water supply alternative which proposes to collect ground water from Railroad Valley and transport it to be Las Vegas Metropolitan subarea requires over 200 miles of aqueduct. This alternative would include one pumping plant to lift the water approximately 900 feet. A 2-mile tunnel would also be required through the North Pahranagat Range. In this alternative water plan it has been assumed feasible to construct a power plant because the power costs from such a plant would be less than purchased power costs. The power plant would be located below the tunnel in the North Pahranagat Range. From the power plant at an elevation of 3,910 feet, the water would flow by gravity to a terminal reservoir near Nellis Air Force Base at an elevation of 3,030 feet. The costs of this aqueduct system are given in Table 1.

Pahranagat Valley. The fourth intrastate water supply alternative involves extracting ground water from Pahranagat Valley. More than 100 miles of aqueduct would be required in this alternative to transport water from an elevation of 3,900 feet at the well field down to an elevation of 3,090 feet at the terminal reservoir near Nellis Air Force Base. One small pumping station would be required. The costs of the system are tabulated in Table 1.

Virgin Valley. If credit can be obtained for the flow discharged into Lake Mead from the Virgin River, it would be possible to recover the water from Lake Mead in a manner similar to the SNWP. The cost of this recovery has been estimated to be the same as that for the SNWP after updating construction costs and changing the interest rate. It should be noted, however, the Virgin Valley could not supply all the water to meet the anticipated demand.

Capital and unit costs (including operation and maintenance and amortization) for each plan are given in Table 1.

The effect of a lower interest rate should be noted. If instead of 7 percent, a 5-1/8 percent interest rate

TABLE NO. 1

CAPITAL AND UNIT WATER COSTS FOR INTRASTATE IMPORTATION PLANS

	High Population Projection			Low Population Projection		
Project	Capital Cost	Unit Cost Delivered	Unit Cost Delivered & Distributed*	Capital Cost	Unit Cost Delivered	Unit Cost Delivered & Distributed*
Pahrump Valley	$237 million	$186/ac.ft	$248/ac.ft	$185 million	$168/ac.ft.	$230/ac.ft
Amargosa Desert	$295 million	$270/ac.ft	332/ac.ft	$227 million	$225/ac.ft.	287/ac.ft
Railroad Valley	$474 million	$252/ac.ft.	330/ac.ft	$372 million	$268/ac.ft.	314/ac.ft
Pahranagat Valley	$246 million	$214/ac.ft.	276/ac.ft	$192 million	$178/ac.ft.	240/ac.ft
Virgin Valley	---***	$ 63/ac.ft.**	125/ac.ft	---***	$ 63/ac.ft.**	125/ac.ft

* Cost to ultimate consumer

** Estimated unit cost based on using Lake Mead for storage, blending and conveyance.

*** The capital cost of the Virgin River project would depend upon the amount of upstream use.

(corresponding to the FY1971 rate on federal loans for water projects) had been used the effect would have been to reduce the unit price of water about 20 percent in the case of Railroad Valley and Virgin Valley plans and about 15 percent in the case of Pahrump, Amargosa and Pahranagat plans.

Interstate Plans

In addition to the alternative intrastate water supply plans, there are several interstate alternatives considered in this study. Two different categories of interstate water plans have been investigated. One category consists of regional water plans which were developed to transfer large quantities of water from one region of the country to another. All of these plans involved interstate movement of water. The second category pertains to developing a desalinization plant. Although the interstate plans investigated in this study have not been intended to be an all-inclusive list, they are a representative sample of the best known alternatives.

Since the regional water plans were proposed in the middle 1960's, their cost analysis had to be adjusted to reflect 1970 construction costs and an assumed interest rate of 7 percent. Also, it has been necessary to add to the construction cost the following costs in order to make the economics comparable to those for the intrastate plans: contingencies, engineering, legal, administration, and financing costs. These three adjustments have been made and the costs for the regional plans have been recomputed accordingly.

Snake-Colorado Project. This plan was presented by Samuel B. Nelson of the Los Angeles Department of Water and Power in 1963. Nelson proposed to divert 2.4 million acre feet per year from the Snake River and transport it to Lake Mead, a total distance of about 520 miles. From Lake Mead, some of this water could be diverted for use in the Las Vegas Metropolitan area.

The unit cost for water delivered to Lake Mead was shown to be $32 per acre foot in Nelson's economic analysis. This cost was updated to reflect 1970 costs, a 7 percent interest rate, contingencies and non-construction costs. Finally a cost of $63 per acre foot has been added as an estimate of the cost of treating and transporting the water from Lake Mead to the Las Vegas Metropolitan subarea. The total up-dated unit cost has been determined to be $175 per acre foot of treated water delivered to the Las Vegas Metropolitan subarea.

Sierra-Cascade Project. The Sierra-Cascade Project was presented in 1964 by E. Frank Miller. This plan was larger in scope than the Snake-Colorado Project since it proposed to divert up to 30-million acre feet per year from the lower Columbia River and eventually transport it to Lake Mead.

The economic analysis presented in this project was very complicated. An adjusted cost analysis for this project has not been made because the time required for this analysis was beyond the scope of this study.

Modified Snake-Colorado Project. The last regional water importation plan investigated in the study was the Modified Snake-Colorado Project. This plan was proposed in its final form by William G. Dunn in 1965. In this plan Dunn proposed to divert 15-million acre feet per year from the lower Snake River and the Columbia River and transport it to Lake Mead through a 1,016-mile aqueduct. This plan was claimed to provide eleven western states with adequate water supplies for a period of 50 to 60 years.

The economic analysis presented by Dunn indicates that the cost for water in this plan would be $37.60 per acre foot. This cost was based on a 3 percent interest rate and 1965 construction costs. By making the same adjustments as before, the adjusted unit cost has been determined to be $128 per acre foot. After adding the $63 per acre foot for transportation and treatment of the water from Lake Mead to Las Vegas, the total unit cost has been computed to be $191 per acre foot of treated water delivered to the Las Vegas Metropolitan subarea.

Desalinization. The second category of interstate water plans investigated in this study is desalinization of sea water. In this analysis it has been assumed that a desalinization plant would be built on the Pacific Coast in southern California. The potable water from this plant would be delivered to the Metropolitan Water District of Southern California (MWD) in exchange for an equal amount of MWD's share of Colorado River water.

Costs associated with this analysis can be separated into two divisions. The first is the cost of producing the potable water and transporting it to the MWD system. The second division includes the cost of delivering and treating the exchanged MWD water from Lake Mead to the Las Vegas Metropolitan subarea.

A cost analysis has been made to determine the approximate cost of constructing and operating a desalinization plant along the California coast near Los Angeles. This economic analysis indicated that for a 7 percent interest rate and 1970 construction costs the unit cost for desalinization and delivery to MWD would be approximately $149 per acre foot. The cost of delivering and treating the water from Lake Mead to the Las Vegas Metropolitan subarea has been estimated to be $63 per acre foot. It has been assumed that the cost saved by MWD in treatment and transportation costs would be nearly $12 per acre foot of treated water. The net unit cost has been determined to be $200 per acre foot of treated water delivered to the Las Vegas Metropolitan subarea.

ALLEVIATING WATER SHORTAGE BY REDUCING CONSUMPTION, REDISTRIBUTING POPULATION, OR LIMITING POPULATION

Reduction of Per Capita Consumption

One alternative solution to the impending water shortage of the Las Vegas Metropolitan subarea is to reduce the consumption of water. By reducing the per capita water consumption it would be possible to completely avert a water shortage through 2020. It has been estimated that if the per capita consumption could be reduced by 28 to 39 percent the water shortage problem would be solved for the study period.

Water consumption rates exhibit a great variation across the country, ranging from around 50 gallons per capita per day (gpcd) to over 500 gpcd. The Las Vegas Metropolitan subarea consumption rate has been estimated at approximately 475 gpcd. This can be compared with the corresponding current consumption rate in Tucson, Arizona, which has a similar climate, of about 200 gpcd.

The affluence of the residents and the climate of the area are largely responsible for the great range in per capita consumption rates. In the Las Vegas Metropolitan subarea, approximately 70 percent of the summer water use is devoted to uses outside of the home. Watering lawns and other green areas accounts for the bulk of this outside use, and it is in these areas of water use where the greatest curtailment can be realized.

In order to curtail water consumption in the Las Vegas Metropolitan subarea, it would be necessary to provide an economic incentive to the water users or to create a sense of conservation among users. Increased water rates to cover the cost of obtaining water from the next supply source would have a two-fold beneficial effect. First, it would generate revenue for financing additional water projects; and second, the economic factor of increased water rates would result in reduced consumption.

It appears feasible to reduce per capital water consumption by increasing rates about 100 percent. The effects of this alternative would be to change the pattern of water use. In a large measure, the acceptance by the population that the southern Nevada area is arid and hence not as able to maintain the greenery they might have been accustomed to in more humid environments would greatly help to reduce consumption. The residents of Tucson have, to a large degree, adapted to the desert climate, as evidenced by their water consumption of 200 gpcd. A reduction in the Las Vegas Metropolitan subarea to about 325 gpcd would be sufficient to avert the predicted water shortage problems.

Population Redistribution

Another possible solution to the impending water shortage problem which requires no additonal water supplies for the Las Vegas Metropolitan subarea is population redistribution to subareas where excess water would be available if stored ground water were to be mined. Two possible stimulations might attract population dispersion. In the first case, industrial activity in outlying areas could be encouraged by offering industry economic advantages. This type of activity would result in development of supporting activities and consequent population growth. The second stimulation would be to provide economic advantages to people to live in the subareas away from Las Vegas. In both of these cases, population dispersion could be accomplished; and there would be no need to import water into the Las Vegas Metropolitan subarea.

The growth effects of large cities are such that as a city expands in population the cost of living rises while the standard of living falls. As more and more people take up residence, congestion leads to all the consequent problems of air pollution, uncleanliness, crime, etc., while at the same time rents and other living costs tend to get higher. In light of this reasoning, it is evident that a dispersed population in a certain sense results in a more desirable way of life. However, there are numerous advantages to urban life, some of which include a wider range of services and a wider economic base.

There are many difficulties related to accomplishing an effective program of population dispersion. No sure method exists since people cannot be forced into dispersing against their wills. Encouragement must be offered through economic advantages to disperse, and the amount of economic advantage needed to induce people to move is open to question. Based on the high population estimate, it has been estimated that as many as 450,000 people might be located somewhere outside the Las Vegas Metropolitan subarea by the year 2020. All of the subareas, excepting remote Railroad Valley, appear to offer potential sites for increased population. Should population dispersion be effected and an increase in population experienced at the various subareas, the economy of these subareas is expected to realize a drastic change since in most cases, the existing base industry for the subareas is small and is related to tourism and agriculture.

In order to accommodate the expansion attendant with population dispersion, a quick and convenient means of traveling between the outlying subareas and the Las Vegas Metropolitan subarea would be desirable for the approximately 80,000 people who would commute to Las Vegas each work day. On that basis, a mass transportation study has been made to determine its feasibility. For this study, it was assumed that 15,000 commuters would travel by car. A total round trip 120 miles has been taken as representative of the distances to the potential subareas for accepting dispersed population. Four different modes of travel were investigated: bus, automobile, tracked air cushion vehicle (TAVC) and airplane, Using current fares and an estimated fare in the case of the TAVC, daily commuting costs were computed. It was found that the total annual costs of commuting would be more than double the annual costs of an aqueduct system to bring sufficient water to Las Vegas. Hence, it appears that factors other than economic must be used to justify population dispersion.

Limiting Population Growth

If it were possible to limit the population of southern Nevada, or more specifically the Las Vegas Metropolitan subarea, to 72 or 61 percent of the projected low and high populations respectively in the year 2020, a water shortage could be averted. Projected populations for the Las Vegas Metropolitan subarea for year 2020 range from 1,100,000 to 1,300,000. The water supply available to the Las Vegas Metropolitan subarea (50,000 acre feet from wells, 281,000 acre feet from the mainstem of the Colorado River, and 30 percent recovery and reuse of the two previous sources) would support a population of 800,000 people in the manner to which they are presently accustomed. While there are conceivable methods of controlling population growth, there are a few which would not adversely affect present residents. One possibility for controlling growth would be to encourage a reduction in the birth rate within the State. This policy if accepted and adopted by Nevada could conceivably control growth from within the State but would be ineffective against controlling migration to the State.

A possibility for controlling growth which would be effective against migration is to control or limit economic growth. This could be accomplished by zoning, excessive taxes, severe anti-pollution requirements, etc. This approach to population control presupposes that people would not locate in an area in which it would be impossible to find employment. While such economic measures may effectively inhibit population growth it cannot be pursued without adversely affecting the present residents.

COMPARISON OF ALTERNATIVES

Several solutions to the impending water shortage in the Las Vegas Metropolitan subarea have been studied. Cost analyses are given for water importation plans; but because of the intangible economics involved in population dispersion and reduction in per capita consumption and limiting population growth, no cost analysis is given for these alternatives. Table 2 gives a summary of the unit costs for the various water importation plans. This table indicates that the cost for the needed additional water supplies for the Las Vegas Metropolitan subarea will be much higher than today's water costs regardless of the alternative plan chosen.

A significant difference exists between the intrastate and interstate water importation plans. The intrastate plans are not dependent upon an agreement for interstate movement of water. In other words, the State of Nevada has within its boundaries the wherewithal of choosing and implementing one of the intrastate water plans. However, Nevada must depend on the acceptance of other states of a regional water plan before any of the interstate plans can be implemented.

The first alternative plan which did not involve water importation is the reduction of per capita consumption. This alternative appears to be the most economical solution because it creates funds for financing water supply plans, while at the same time reducing the demand for water. In addition, this alternative would cause a greater awareness by the population of the value of water in an arid climate, thereby promoting a more efficient use of this valuable resource by curtailing wastage and excessiveness.

It appears that population dispersion is not an economic means of solving the water problem. Transportation costs would be high and difficulty would be encountered in trying to attract people to the outlying areas.

If definitive action were taken to inhibit the projected population increases and these actions were successful in reducing the projected population at least 28 or 39 percent for the low and high projected populations respectively, then southern Nevada would not experience a water shortage. Although there are advantages associated with restricting population growth it is difficult to conceive of a deterrant to population growth which would not also adversely affect the present residents of Nevada.

As mentioned earlier, the plans investigated in the study are not intended to be all-inclusive of every conceivable solution of southern Nevada's impending water shortage problem. They represent what is believed to be a representative sample of the possible solutions. Based on the analyses given in this report, it should be possible to eliminate the least desirable plans and proceed with a more detailed analysis of those which appear most desirable.

TABLE NO. 2

COMPARISON OF UNIT WATER COSTS
IN $/AC. FT.

Plan	Cost Delivered to Las Vegas Valley L.G.R. *	Cost Delivered to Las Vegas Valley H.G.R. *	Cost of Water Including Distribution Costs*** L.G.R.	Cost of Water Including Distribution Costs*** H.G.R.
Cost of Water in L.V.V. today			90	
Intrastate Plans				
Pahrump Valley	168	186	230	248
Amargosa Desert	225	270	287	332
Railroad Valley	252	268	314	330
Pahranagat Valley	178	214	240	276
Virgin Valley	63	63	125	125
Interstate Plans **				
Snake Colorado Project	175		240	
Modified Snake-Colorado Project	190		255	
Desalinization	200		265	

* A unique unit cost is specified by one population estimate, range of unit cost indicates the range expected on the basis of high and low population estimates.
H.G.R. = High Growth Rate L.G.R. = Low Growth Rate

** Price for water for interstate plans is unaffected by population growth rates of Nevada.

*** Cost to ultimate consumer.

I PART 2 INTRODUCTION

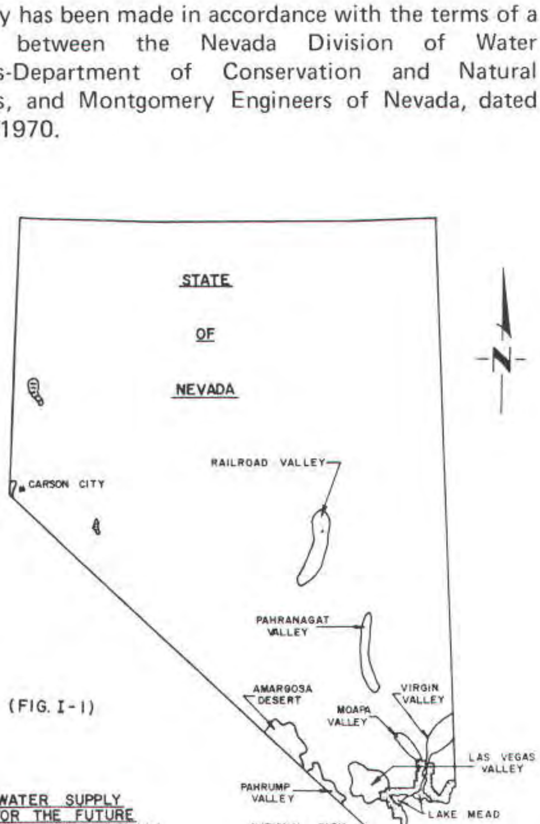
INTRODUCTION

1.01 GENERAL

A narrative overview of the municipal and industrial water situation in southern Nevada between 1970 and 2020 is presented in Part 1 of this report. A cursory reading of that portion of the report may suffice for those only casually interested in the subject. A more detailed explanation of the various items summarized in Part 1 is contained in Part 2.

1.02 AUTHORIZATION

This study has been made in accordance with the terms of a contract between the Nevada Division of Water Resources-Department of Conservation and Natural Resources, and Montgomery Engineers of Nevada, dated March 2, 1970.



(FIG. I-1)

WATER SUPPLY FOR THE FUTURE IN SOUTHERN NEVADA

LOCATION MAP SHOWING STUDY AREA BOUNDARIES

1.03 STUDY AREA

The study area for this report is a portion of southern Nevada. It includes all of the subareas which receive or are scheduled to receive water from the Colorado River Mainstem. This group is composed of the Las Vegas Metropolitan subarea, Fort Mojave subarea, and Lake Mead National Recreation Area subarea. Additionally, the study area includes the subareas drained by the Muddy and Virgin Rivers; namely, Moapa Valley and Virgin Valley subareas. Finally, the study area includes those outlying hydrologic basins which may have water available for export by mining ground water and which are not too far removed from the population centers of southern Nevada. This group contains Pahrump Valley, Amargosa Desert, Railroad Valley and Pahranagat Valley. The study area is shown on Figure I-1.

1.04 SCOPE OF REPORT

In accordance with the terms of the contract, the following studies have been made for the study period extending to the year 2020:

1.04(a) Population Projections and Future Water Requirements

Population predictions and future municipal and industrial water requirements have been estimated for each subarea based on no shortage of reasonably priced potable water in each subarea. These projections have been made through the year 2020.

Not included in the totals are numerous small communities in southern Nevada because of their minor effect on large-scale water planning. However, they should be considered at the time more definitive plans are made for supplementing southern Nevada's water supply.

1.04(b) Local Water Supplies

The quantity and quality of local water supplies, both underground and surface, available in each subarea, have been studied. The feasibility of utilizing reclaimed waste water for potable water purposes also has been investigated.

INTRODUCTION

1.04(c) Comparison of Water Resources and Demands

In each subarea a comparison has been made of the local water supply available, including ground water mining of the equivalent amount of water in the upper 100 feet of saturated material, with the future requirements of the subarea. In some subareas neither a deficiency or an excess has been estimated to occur on this basis because the population growth in the subarea is limited by the amount of water available and importation is not considered feasible through the year 2020.

1.04(d) Supplemental Water Supply from Sources Within Nevada

The costs and effects of importing water to the area of deficiency, Las Vegas Metropolitan subarea, from various subareas with either a surplus of surface flow or ample ground water that could be mined have been estimated.

1.04(e) Supplemental Water Supply from Sources Outside Nevada

The costs of importing water to the Las Vegas Metropolitan subarea, from selected sources outside Nevada have been included in this report for ease of comparison. These basic costs were prepared by others and have been updated and standardized for the purpose of this report.

1.04(f) Alleviating Water Shortage by Reducing Consumption

A plan to preclude the necessity of importing water to the Las Vegas Metropolitan subarea has been formulated. This plan envisions a reduction of water consumption through judicious pricing of water.

1.04(g) Alleviating Water Shortage by Population Redistribution

The methods of achieving and the resulting effects of redistributing a portion of the future population in southern Nevada have been investigated. This plan contemplates population increases in subareas with water surpluses and population limits in other subareas based on availability of water.

1.04(h) Alleviating Water Shortage by Limiting Population

The possibility of limiting the growth of southern Nevada has been studied as an alternative means of reducing or eliminating the projected water shortage.

1.05 CONTRIBUTIONS BY STATE ENGINEER'S OFFICE

The preparation of this report was made in close cooperation with the State Engineer, Mr. Roland D. Westergard, and members of his staff, particularly Mr. B. James Vasey. Messrs. Westergard and Vasey assisted greatly during the course of this study by taking a very active part in numerous planning meetings and by furnishing needed material in an efficient manner. Also, representatives of the State Engineer's Office did much of the research work required for this study.

The information pertaining to water supplies from the Colorado, Muddy and Virgin Rivers was compiled by the State Engineer's office. The same is true for most of the data concerning ground water.

Without the able assistance of the State Engineer's office, the preparation of this report would have been more arduous, taken longer, and been more costly. This assistance is warmly acknowledged.

1.06 ACKNOWLEDGMENTS

In addition to the State Engineer's office, innumerable governmental agencies, private organizations, and universities assisted with this study. Representatives of these groups were universally generous with their time and contribution of much valuable information. Unfortunately, individuals involved are simply too numerous to name. However, the following is believed to be a comprehensive list of agencies and organizations which contributed ideas, advice and information so necessary in the preparation of a report of this type:

U.S. Bureau of Reclamation
U.S. Office of Saline Water
U.S. Bureau of Census
U.S. Bureau of Wildlife
U.S. Bureau of Land Management
U.S. Geological Survey
U.S. National Park Service
U.S. Weather Bureau
U.S. Atomic Energy Commission
Colorado River Commission of Nevada
Colorado River Board of California
California Department of Water Resources
Metropolitan Water District of Southern California
Desert Research Institute
Nevada Department of Fish and Game
Nevada Agricultural Extension Service
Nevada State Division of Health
University of Nevada at Las Vegas
Las Vegas Valley Water District
City of Las Vegas

1.06 ACKNOWLEDGMENTS (Cont'd)

City of North Las Vegas
City of Henderson
City of Boulder City
City of Tonopah
Southern Nevada Industrial Foundation
Sierra Pacific Power Company
Nevada Power Company
Clark County Library

II PART 2 STUDY AREA CHARACTERISTICS

STUDY AREA CHARACTERISTICS

2.01 GENERAL

2.01(a) The Southern Nevada Economy and Its Growth Potential

The metropolitan area of Clark County has had one of the most rapid growth rates of all American urban areas. This is dramatically illustrated in Table II-1.

This rapid growth has been produced by the location of two major unrelated base industries in the area. The two industries, tourism-gaming-entertainment on one hand, and military-nuclear research-heavy industries on the other, have experienced especially great growth since the end of World War II. With their expansion has come a derived growth of supporting activities in trade, services, utilities and local government resulting in a current civilian labor force of 120,000 gainfully employed out of 270,000 population.

The tourism-gaming-entertainment complex is, by far, the more important base of the two with direct employment of about 34,000. The other base component, military-nuclear research-heavy industy, is less well inter-related and far less important. This probably involves nearly 16,000 gainfully employed working for both private firms and the federal government.

Nuclear research and rocket development provide employment for about 10,000 people. Although many of these people work outside of Las Vegas at the Nevada Test Site, the overwhelming majority of them live in or near Las Vegas and are a part of the metropolitan southern Nevada economy.

In addition, there is a sizeable resident military and civilian labor group employed at Nellis Air Base and at other smaller military bases in the area. Lastly, at Henderson there exists a heavy industrial complex which originated with the use of Hoover Dam power during World War II to produce magnesium. The principal employers in this complex are American Potash and Chemical Corporation, Stauffer Chemical Company, Titanium Metals Corporation of America, and U.S. Lime.

Year	Clark County	Las Vegas	North Las Vegas	Henderson	Boulder City
1920	4,859	-	-	-	-
1930	8,532	-	-	-	-
1940	16,414	8,422	1,967	-	-
1950	48,249	24,624	3,875	5,419	3,904
1960	127,016	64,405	18,422	12,525	4,059
1970*	270,045	124,161	35,315	16,129	5,139

*Preliminary figures.

TABLE II–1

POPULATION OF SOUTHERN NEVADA

Numerically, the Las Vegas economy of 1970 may be thought of in these employment terms:

Employment Category		Estimated Employment
Base Industry Group I		
Tourism-Gaming-Entertainment		34,000
Base Industry Group II		
Nuclear Testing Research	10,000	
Military (civilian employment)	2,000	
Heavy Industry	4,000	16,000
Total Base Industry Employment		50,000
Derived Employment		70,000
Total Employment		120,000

Thus, employment of 50,000 people in base industry apparently has resulted in the employment of 120,000 people in the Las Vegas Metropolitan subarea. From these statistics, an employment multiplier in the Las Vegas area of 2.4 can be derived. That is, for every new job in the hotel casino, recreation area, nuclear test, military base or industrial plant, there is likely to be additional employment of 1.4 in other trade, service, utility and local government activities for a total rise in employment of 2.4

It should be noted that each of these driving forces, the "Leisure" industry and the "Research-Defense" industry, represents a new industrial category for the United States. Las Vegas, in the past two decades, has been one of the principal beneficiaries of the rise of these activities.

STUDY AREA CHARACTERISTICS

2.01(b) Population Projections and Their Limitations

It should be obvious that significantly accurate population projections for a period of fifty years through to the year 2020 are almost an impossibility. As the time span widens from ten years in the future to fifty, the difficulties of forecasting become greater. In the 1930's it was expected that United States population, then 130 million, would increase to between 160 and 170 million by 1970-80, at which time it would level off. The 1970 census just released shows that population to be 203 million, not 160 million. Entirely unanticipated by the population forecasters of the 1930's was the marked increase in the birth rate beginning after 1945 and continuing for nearly 20 years. From the 1930 view of dampened population growth and eventually a stable population, informed opinion swung after World War II to the acceptance of continuous population growth. Discovery of the population upswing in the 1950's was viewed with satisfaction as providing prosperity and an underpining to an ever increasing demand for goods. Business became growth conscious.

Today considerable disillusionment has set in with regard to growth. It has been discovered that while population growth stimulates the economy, it gives rise to a host of social problems, most of these clustering around the deterioration that has been occurring in many of our great cities. Thus it is not surprising to find many people in southern Nevada asking how population growth in the area may be checked. The assumption made is that southern Nevada will be overwhelmed with population unless something is done in the future to check its growth. Limited local water supplies have been viewed as a factor that might eventually bring about a halt in growth. Before examining this concept, it is well to examine the matter of changing views on population growth.

Simultaneously with the release of 1970 census statistics which have conformed quite well with the estimates of ten years ago, the Bureau of the Census has just made a substantial revision of its future estimates of population (1). This revision must call into question all long run local and regional estimates of population growth which have been based not merely on an area's acquiring a disproportionately high part of American population growth, as has Nevada, but which have been based on expectations of high growth of population for the nation as a whole.

The new low projection estimate is 27 percent below the old high estimate. This range of forecasts dramatizes the difficult problem of making a national forecasting for a period as much as 30 years ahead.

The disturbing factor for such estimates has been a change in the birth rate from 3.24 children per woman of childbearing age which prevailed from 1945 to 1965 to the rate of 2.45 today. If the birth rate should fall further to 2.11, population would continue to rise until it would reach the new census low estimate figure of 266 million in year 2000. Actually, a rate of 2.11 would merely replace the existing population, but population would continue to increase for a while due to the disproportionate number of women who are in the childbearing age group and because of the net immigration to the United States.

Estimate	Old Census Projections Year 2000	New Census Projections Year 2000	Difference Year 2000	Percent Decrease
High Estimate	361 Million	320 Million	41 Million	11%
Low Estimate	283 Million	266 Million	17 Million	6%

If the birth rate should rise to 3.1 and remain at that level, population would increase to the new census high estimate of 320 million for the year 2000. This would be a 60 percent increase in population from 1970 to 2000. A lower rate of 2.78 would produce an intermediate population figure of 301 million for 2000 and would represent a 50 percent increase in population between 1970 and 2000.

The significance of these examples is to put all population estimates, including southern Nevada estimated growth, in perspective. Population growth for the nation can undergo marked change, as just shown, upon the basis of the changes in birth rates. It is from the rest of the United States that southern Nevada must draw its growth in addition to its relatively small internal growth from local births. For Las Vegas to grow to one million by 2000 it will have to grow at a rate of from five to ten times more rapidly than the National growth rate, depending of course on the rate of growth actually experienced by the Nation. If economic attractions are sufficient, ten fold greater growth is conceivable, but southern Nevada growth will materialize more readily with a more rapid growth of the national population. In the future, population growth of the nation is not likely to be as substantial a supporting factor to southern Nevada's growth as it has been in the past.

2.01(c) Basic Assumptions for Population Projections

Several basic assumptions have been made to serve as guide lines for projecting population growth in southern Nevada. These assumptions are:

1. The national economy will continue to grow and economic recessions of significance will be avoided.

2. The general level of affluence will continue to rise in the nation in pace with economic growth.

3. The trend toward shorter work weeks and increased leisure time will continue.

4. No major war will occur.

5. The redistribution of population to the western states will continue.

6. Gaming will continue to be legal in Nevada, but will not be expanded in adjoining states, and there will be no significant federal controls imposed on gaming.

7. Interrelationships between sectors of the Nevada economy will remain constant or change in a predictable fashion.

2.01(d) Geographic Distribution of Future Populations

Population projections for the Las Vegas Metropolitan subarea, consisting of the cities of Las Vegas, North Las Vegas, Henderson and Boulder City and the unincorporated areas immediately adjacent have been prepared on the basis of previous projections and the results of the 1970 census. These projections are given in Table II-2.

The growth of Las Vegas to date has had virtually no affect on towns within a 50 mile to 100 mile radius. The population of Alamo, Bunkerville, Mesquite, Moapa, Overton and Logandale, has remained practically the same for many years. Dispersion from metropolitan Las Vegas may be delayed for some time due to the fact that unlike most American cities it is very new. The attractions of better housing outside the metropolitan area are, therefore, not likely to exercise the pull that they have exercised currently in other American cities. Las Vegas has been built as an automobile city and it does not now and is not likely for some years to come, to present the congestion problems found in other cities. Also available land for building within the metropolitan area is sufficient to readily accommodate a population of a million.

Population projections for areas other than Las Vegas have been made as part of this study simply to furnish benchmarks for the purposes of the report. These projections are given in Table II-2. The projections have been made on the basis of the following considerations:

1. Population growth in the future of presently small or non-existent communities will not generally be of the steady individual accretion type of the past. New communities will be planned and built rapidly, if built at all, by huge real estate organizations or governmental agencies. For this reason, Fort Mojave and Pahrump which are currently being promoted by real estate firms are considered to have better growth possibilities than other communities such as the Moapa and Virgin Valleys.

2. Proximity to great metropolitan areas will be

TABLE II–2

POPULATION PROJECTIONS WITH BASE GROWTH ONLY

Subarea	1970 Estimated Population	1980		2000		2020		Most Probable Population in 2020
		Low	High	Low	High	Low	High	
Metropolitan Las Vegas	265,000	300,000	500,000	610,000	1,000,000	1,100,000	1,300,000	1,200,000
Fort Mojave	50	100	20,000	100	40,000	100	60,000	50,000
Moapa Valley	2,200	4,000	20,000	8,000	30,000	12,000	50,000	20,000
Virgin Valley	1,100	2,000	4,000	4,000	5,000	8,000	10,000	10,000
Pahrump Valley	1,200	2,000	20,000	5,000	50,000	10,000	100,000	10,000
Amargosa Desert	1,500	1,500	2,000	1,500	5,000	1,500	10,000	5,000
Railroad Valley	100	100	200	100	200	100	200	100
Pahranagat Valley	300	300	1,500	300	2,000	300	2,500	2,500

important to growth. Thus communities near southern California, such as Pahrump and Fort Mojave probably have better growth prospects than those which are farther removed, especially since the general growth of the area is felt to depend chiefly upon tourism and recreation as base industries.

3. Existence of good transportation or prospects of such facilities are likely to attract real estate development firms to an area or stimulate its growth through individual action. This factor favors communities such as the Moapa Valley and the Virgin Valley which are presently served by Interstate 15.

4. The decline of small communities without prospects of keeping or attracting base industries will continue. Nevada has already known this phenomenon with the decline of mining communities. Population movement from rural areas and smaller communities to urban areas will continue. Nevada, unlike other sparsely populated states is an urban state.

5. Available water supplies will affect growth prospects at least in initial stages of growth. Real estate developers planning new communities will certainly not wish to encumber themselves with the problems of aqueduct systems and high cost water when lower cost water exists elsewhere. Thus development will be confined to the areas that have water. Later, once a community has attained size, local water resources will be less important, since expensive water systems can then be financed to serve its growth.

2.01(e) Basis and Sources of Water Requirement Predictions

The future water requirements for the Las Vegas Metropolitan subarea are based on the population projections previously described. In estimating the future water requirements, it has been assumed that the existing per capita use of water (475 gpcd or 0.532 acre feet per year per capita) in this area will increase at the rate of 2.5 percent each ten years. This upward trend is typical of that found throughout the United States in recent years and is attributable to an increasing number of water-using conveniences plus the general affluence of the populace.

The future water requirements for the Las Vegas Metropolitan subarea, LMNRA, Virgin Valley, Pahrump Valley, Amargosa Desert, Railroad Valley, and Pahranagat Valley subareas, are predicted upon an abundant supply of economically priced water. The future water requirements for the Fort Mojave and Moapa Valley subareas are based on a limited supply of water with no additional supply becoming available during the study period.

2.01(f) Waste Water Utilization

As the sources of "virgin water" rapidly disappear from the arid portions of the United States, utilization of reclaimed waste waters becomes increasingly attractive. Looking ahead to the end of the 20th century, it appears mandatory for the urbanized portion of southern Nevada, and perhaps some isolated communities, to productively use the waste water generated within the area. There are still many problems associated with the reuse of waste water, including bacteriological and viral contamination, salt buildup, nitrate and phosphate pollution, appearance and of course, public acceptance. Extensive research is underway throughout the world to find economically feasible means of treating and handling sewage so that it may be used as a supply of potable water. It is assumed for the purposes of this report that these means will be found. Further, it has been assumed that 30 percent of the potable water demand can be supplied from reclaimed waste water.

2.01(g) Water Supply Within Nevada

2.01(g)I General. Nevada, particularly southern Nevada, has a dearth of surface streams to which urban areas can go in order to satisfy their desires for water. Fortunately, however, nature has been storing water underground in many of the valleys of southern Nevada for eons. This stored water, for all practical purposes, is available for one time only and future generations should be considered if it is mined.

A representative sampling of those sources of water occurring in Nevada and within a reasonable distance of Las Vegas has been considered as a supplemental supply. Other basins exist as potential sources of supply and should be studied if interest in interbasin transfer of water increases. The most remote source has been taken as Railroad Valley, some 175 miles from Las Vegas. Only sources with a comparatively large amount of water available for export have been considered in this study. Combinations of sources for importation have not been considered at this time. Later studies may indicate the desirability of combining some sources.

It has been assumed in this study that an amount of ground water equivalent to that contained in the upper 100 feet of saturated valley fill is to be considered available for interbasin transfers or population dispersions.

The sources of information regarding the water supply in southern Nevada were primarily State of Nevada reconnaissance series reports, United States Geological Survey papers, United States Bureau of Reclamation reconnaissance investigations, and an estimate of the ground water resource in several hydrologic units prepared by the Nevada State Engineer.

2.01(g)2 Interbasin Movement of Ground Water. One of the characteristics of the Basin and Range Province, which includes the entire state of Nevada, is the interbasin movement of ground water. In other words, the many closed intermountain basins in the state are in many cases not closed groundwater basins. Hence while all the surface runoff within a closed topographic basin will drain towards the lowest point within the basin and then be lost through evaporation and infiltration, ground water will move into and out of the basin from and to adjoining basins.

Many studies have been made during the past decade to investigate the extent to which interbasin movement of ground water occurs within Nevada. Some of the earliest reports investigated the possibility of movement of radioactive pollution in the ground water from the Nevada Test Site to areas where ground water was extracted by pumpage or released through springs. Subsequent studies sponsored cooperatively by the Nevada Department of Conservation and Natural Resources and the United States Geological Survey have been concerned with more general topics of interbasin movement. These reports have indicated that regional ground water systems do exist within the state. Winograd (2) stated that the similar elevations of static water levels in Yucca, Frenchman, and Jackass Flats "suggested a hydraulic connection between the three basins..." He further concluded that the hydraulic gradient of the area indicated that ground-water flow was toward the Amargosa Desert; and thence, the discharge from the springs in eastern Amargosa Desert at Ash Meadows consisted in part of ground water from these three basins.

Later studies by Worts, Eakin, and Rush (3,4,5) pointed to regional ground water systems within the carbonate bedrock of the eastern two-thrids of the state. They stated that the great thicknesses of Paleozoic carbonate rocks which underlay the younger alluvium and volcanics accepted water by downward percolation from the overlying beds and transmitted this ground water through solution cavities from basin to basin in a regional ground-water system.

Because closed topographic basins may be connected by a regional ground water system, extraction of ground water from one basin may affect the ground water environment of other basins which are within the same regional system. Some of the plans presented in this report for supplying supplemental water to southern Nevada involve heavy pumpage from various valleys within the state, hence it seems possible that an effect will be felt in basins which have a direct hydraulic connection to the pumped basin. As mentioned earlier, Winograd pointed to the connection between the three basins (Yucca Flat, Frenchman Flat, and Jackass Flats) and the Amargosa Desert. Since one of the intrastate water plans proposes to pump ground water from the Amargosa Desert, the ground-water regime of the three basins is expected to be influenced somewhat. Similarly, since Pahranagat Valley is also a site for pumpage in another water plan and since, as pointed out by Eakin (4), Pahranagat Valley is one of thirteen closed topographic basins within a regional ground-water system, pumpage from Pahranagat can be expected to have an effect on the other valleys of this regional system.

Although the studies mentioned above have indicated that certain closed topographic basins are grouped into regional ground water systems with other closed topographic basins, the magnitude of the effect from pumpage in one basin according to the various intrastate water plans on other basins within the system will most probably be slight except in limited instances. As Worts (3) indicated, pumping from near Devils Hole (part of Death Valley National Monument) would probably take several years to affect the water level at Devils Hole except for certain cases where pumping occurs within approximately a mile. It appears that the most critical intrastate plans, as regards interbasin transfer would be pumping from Pahranagat. Approximately 40 miles down-gradient from Pahranagat is the discharge area for Moapa Valley. Eakin (4) indicated that Upper Moapa Valley was one of the three discharge areas for a thirteen basin-wide regional ground-water system in southeastern Nevada. The springs there provide most of the flow for the Muddy River. Based on information presented in the reference reports alluded to, it seems possible that pumpage from Pahranagat could affect the flow from the springs of Upper Moapa Valley. However, a noticeable effect is not expected to occur until after year 2020. This estimate is preliminary, and a closer investigation would be warranted should planning for the intrastate plan, which proposes pumping from Pahranagat, advance beyond the preliminary stage. A close hydrologic investigation should be completed to determine the effects of interbasin transfer on other basins before any of the intrastate plans is finally initiated.

The ground water basins of two of the subareas, Pahrump Valley and Amargosa Desert, extend into California. If ground water is extracted from the Nevada portion at either of these two subareas, this pumpage could cause a lowering of the ground water levels in the California portion. This would occur because the lowering of the water level by ground water extraction on the Nevada side of these subareas could change the hydraulic gradient such that ground water within California, which previously stayed within that state, would travel toward the Nevada side of the subareas. In other words, an interstate transfer of ground water could occur from California to Nevada.

Because the extraction of ground water from these two subareas would alter the hydraulic gradient and consequently result in an interstate transfer of ground water, it would be advisable to enter into a bi-state compact to govern the extraction of ground water from these two basins.

2.01(g)3 Nevada Water Law Summary. The water law of Nevada is based on and limited to beneficial use and the prior appropriation doctrine, which means that an appropriator who has lawfully put an amount of water to beneficial use, enjoys a right to use that amount of water subject only to prior appropriator's rights and continued beneficial use. Nevada Courts have determined that this right is appurtenant to the land and becomes a property right that will be protected as such. The right can be severed from the land only with the owner's permission or by abandonment or non-use for five consecutive years.

In 1905, the legislature passed the basic water law, found today at NRS 532 to 538 inclusive, which provides that all the water of the state above and below the ground belong to the state and can be appropriated only by complying with the heretofore mentioned statutes. These laws are administered by the State Engineer.

To initiate a legal appropriation, the prospective user must make application to the State Engineer. If there is water available on the source and other prior rights will not be interfered with, a permit is issued, which will ripen into a certificated water right when and if the terms of the permit are complied with, within the time set out in the permit.

Water put to beneficial use prior to 1905 from a surface source and 1913 from an underground artesian source (the respective date of passage of the laws pertaining to these sources), and used continuously since, are known as vested rights, the limit and extent of which must be determined in a court proceeding for this purpose.

Surface water is distributed according to the court decrees and permits thereon, when necessary, under the direction of the State Engineer. Water diversion from a surface source for any use can only be accomplished, legally, under a permit.

A well used to divert underground water for domestic purposes, i.e. for a single family dwelling, limited to 1,440 gallons per day, is specifically exempt from the statutory provisions requiring a permit.

The State Engineer may designate underground basins where supply is critical or problems arise. In designated basins certain types of use may be given preference in allowing new permits, and temporary permits may be issued which are subject to revocation when the users can be supplied from another source. It is anticipated, for instance, that revocable permits in the Las Vegas Artesian Basin will be revoked when water from the Southern Nevada Water Project becomes available.

There is no statutory provision preventing interbasin transfers of water.

Any person wishing to divert water from the Colorado River for use in Nevada must, in addition to securing a permit from the State Engineer, enter a contract with the Colorado River Commission of Nevada, and the Secretary of Interior of the United States.

The 1969 session of the State Legislature, recognizing the need for a plan to insure the orderly development of the state water resource, added the following section to Chapter 532 NRS.

> The State Engineer shall:
>
> 1. Conduct necessary studies and inventories and shall develop a comprehensive water resource plan for the State of Nevada.
>
> 2. Review and evaluate proposals by federal, state and local agencies for flood control and water development projects to insure that such proposals are compatible with the state water resource plan and are in compliance with Nevada water laws.
>
> 3. One of the principles of the state water plan is that "Early attention in the planning process will be directed towards meeting the needs of those areas of the state which presently are experiencing water shortages and those areas which will be water deficient in the near future".

The southern Nevada area was determined to be an area which could experience a water shortage as early as 1993, therefore in keeping with the subject principle the State Engineer's office authorized this study on March 2, 1970.

2.01(h) Water Deficiencies and Water Available for Export

A comparison of future water requirements with the supply available in each subarea, including limited mining of ground water, reveals that there is only one subarea with a projected shortage of water; the Las Vegas Metropolitan subarea. While growth of some other subareas has been assumed to be limited by the availability of nearby water sources, this study is limited to the examination of interbasin transportation of water only to the Las Vegas Metropolitan subarea. Future studies may examine the other subareas in more detail to ascertain the feasibility of importation to those subareas. However, it is believed that such importation to other subareas will be adjunct to the larger importation schemes planned for the Las Vegas Metropolitan subarea and will not materially alter the costs given in this report.

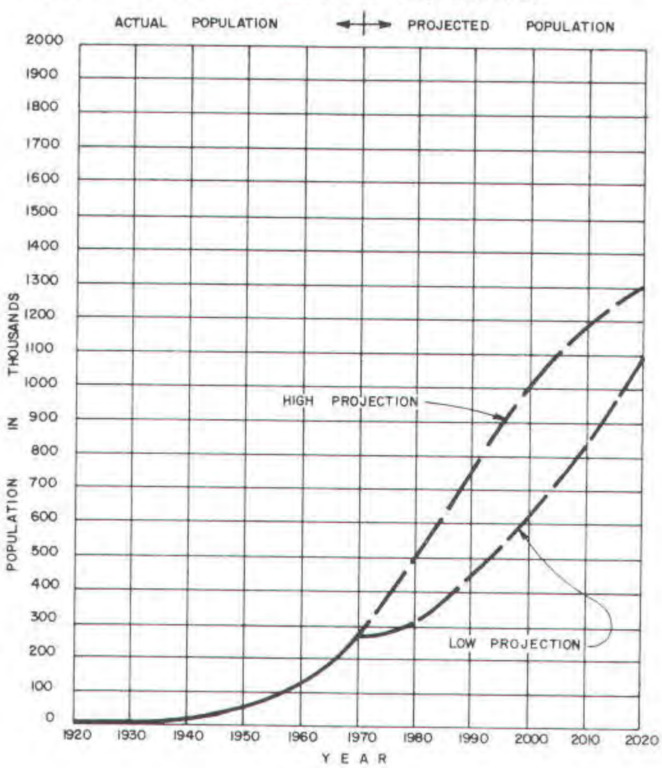
2.02 LAS VEGAS METROPOLITAN SUBAREA

2.02(a) Present and Future Population

The preliminary 1970 census shows a population of about 270,000 for Clark County. Las Vegas Metropolitan subarea, as defined for the purposes of the study, consists of the cities of Las Vegas, North Las Vegas, Henderson, Boulder City and the immediately adjoining unincorporated valley area of approximately 2,000 square miles. The remaining area of Clark County is estimated to contain about 5,000 people. This then gives a population figure for metropolitan Las Vegas as here defined of 265,000 for 1970.

Detailed population projections are given in Table II-2, are shown in Figure II-1 and are discussed in Section 2.01. The most probable population for 2020 is expected to be 1,200,000.

2.02(b) Present and Future Water Requirements



(FIG. II-1)

POPULATION PROJECTIONS IN LAS VEGAS METROPOLITAN SUBAREA

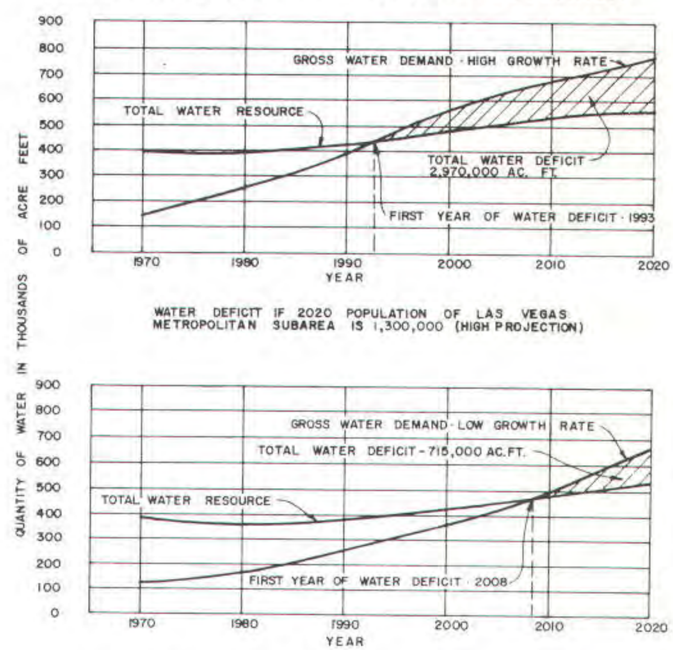
Based on the population projections described above, water requirements for the Las Vegas Metropolitan subarea have been estimated through the year 2020. These water requirements assume that an adequate supply of reasonably priced water will be available. Thus they are assumed to be not affected by artificial stimuli that would tend to reduce the requirements. The projected water requirements are given in Table II-3 and are shown in Figure II-2.

Year	Maximum Water Requirement Ac. Ft. /Yr.	Minimum Water Requirement Ac. Ft. /Yr.
1970	140,000	140,000
1980	270,000	164,000
1990	392,000	249,000
2000	566,000	352,000
2010	662,000	490,000
2020	774,000	660,000

* Based on high and low projected rates of growth.

TABLE II–3

PROJECTED WATER REQUIREMENTS IN LAS VEGAS VALLEY METROPOLITAN SUBAREA



(FIG. II-2) WATER DEFICIT IF 2020 POPULATION OF LAS VEGAS METROPOLITAN SUBAREA IS 1,100,000 (LOW PROJECTION)

COMPONENTS OF TOTAL WATER RESOURCE

1. Withdrawal from Las Vegas Ground-Water Basin 50,000 Ac. Ft. /Yr.
2. Nevada's entitlement of Colorado River water which is available for use in Las Vegas Metropolitan Subarea is approximately 281,000 Ac. Ft. /Yr.
3. Quantity of reclaimed water is 0.3 times the gross water demand.

GROSS WATER DEMAND BASED ON:

1. Present daily per capita use of 475 gallons
2. Per capita water use will increase at the rate of 2.5 percent each 10 year period.

2.02(c) Water Supply

2.02(c)1 Las Vegas Valley Ground-Water Basin. The Las Vegas Valley Ground-Water Basin is divided into two basic systems. The near-surface system is an unconfined (water table) system which derives its water from percolating surface waters of various sources, leaky wells, and a leaking artesian system underlying it. The water surface is within a few feet of the ground surface. The water level in the near-surface system generally has been rising in the valley due mainly to increased irrigation and increased sewage treatment plant effluent flows. Although some wells tap the near-surface system, it is not considered a suitable source for commercial quantities of water because of its doubtful bacteriological and viral quality and its variable chemical quality.

The major ground-water system in Las Vegas Valley consists of three artesian (confined) zones referred to as: Shallow Zone (250-450 feet below the ground surface). Middle Zone (500-700 feet), and Deep Zone (below 700-feet depth). Collectively, these zones are called the artesian system. It is this system which has provided the large quantities of ground water needed in Las Vegas Valley. The artesian system is principally supplied from natural recharge areas in the alluvium at the bases of Spring and Sheep Mountains. Maxey and Malmberg have estimated that the natural recharge from these sources may range from 25,000 to 35,000 acre feet per year (6) (7) .

Natural discharge from the artesian basin is by springs, seeps, and upward leakage to the near-surface system and thence by evapotranspiration. It is estimated that the natural discharge was of the order of 25,000 acre feet per year before the valley commenced to be developed. By maintaining a lowered piezometric level in the artesian system, losses from natural means can be avoided or sharply reduced.

Artificial discharge from the artesian basin by pumping has caused water to be extracted in quantities up to approximately three times the natural recharge. This mining of ground water has resulted in a continuing drop in piezometric levels until today the water level in the Las Vegas Valley Water District main well field is about 130 feet below the surface. This same area was the location of artesian springs in past years. The amount of ground water in storage in the artesian basin is unknown. An ancillary effect of this ground-water mining has been the ground subsidence encountered in the valley, particularly in North Las Vegas.

On March 24, 1955, a section was added to the Nevada Water Law whereby the State Engineer was authorized to "Issue temporary permits to appropriate ground water which can be limited as to time and which may be revoked if and when water can be furnished by an entity such as a water district or a municipality presently engaged in furnishing water to the inhabitants thereof." Revocation of temporary permits in the designated area of the Las Vegas Valley Ground Water Basin issued pursuant to the aforementioned provision of the Law will begin when water from Lake Mead is made available upon completion of the first stage of the Southern Nevada Water Project. The amount of ground water presently being withdrawn from the artesian basin under non-revocable water rights totals approximately 50,000 acre feet per year.

For the purposes of this report, the Las Vegas Valley Ground Water Basin has been considered capable of supplying 50,000 acre feet per year at least until year 2020 which is the end of the study period. This rate of extraction exceeds the natural recharge by 15,000 to 25,000 acre feet per year, but materially reduces losses through upward leakage from the artesian basin. The piezometric level will undoubtedly continue to fall with that amount of pumpage, but not as fast as it has been falling in recent years (4-5 feet per year). Artificial recharge into the ground-water basin would allow a corresponding increase in the withdrawals from the basin.

The quality of the water extracted from the artesian system is generally good. The principal areas of inferior quality ground water are in the southern and eastern sections of the valley. However, the quality of the water underlying most of Las Vegas meets Public Health Service Drinking Water Standards. Typical chemical analyses of Las Vegas Valley ground water are given in Table II-4.

2.02(c)2 Colorado River. Nevada's entitlement to water in the mainstem of the Colorado River is set at 300,000 acre feet per year, based on a flow past Lee's Ferry of at least 7.5 million acre feet per year. The Colorado River Commission of Nevada allocates this water with the concurrence of the Nevada State Engineer and the Secretary of the Interior.

The assumed future distribution of Nevada's 300,000 acre feet per year entitlement is given in Table II-5.

Year	Water Available AcFt/Yr*	Edison Co. Steamplant AcFt/Yr	Fort Mojave Land Develop. AcFt/Yr	Federal AcFt/Yr	Water Avail. for use in Metro. L. V. Subarea** AcFt/Yr
1970	300,000	Nil	Nil	1,000	299,000
1980	300,000	30,000	8,000	2,000	260,000
1990	300,000	25,000	13,000	4,000	258,000
2000	300,000	15,000	13,000	6,000	266,000
2010	300,000	Nil	13,000	6,000	281,000
2020	300,000	Nil	13,000	6,000	281,000

* Does not include credit for return flow.
** Includes water delivered through facilities of SNWP, Boulder City, and BMI.

TABLE II–5

PROJECTED DISTRIBUTION OF NEVADA'S SHARE OF COLORADO RIVER WATER

TABLE II–4

CHEMICAL ANALYSIS OF SELECTED WELLS IN LAS VEGAS VALLEY WATER DISTRICT WELL FIELD

(Concentrations, mg/l (except pH)

	Constituent	USPHS & Nev. Standards	Well					
			#8	#10	#13	#15	#17	#32
Recommended	Alkyl Benzene Sulfonate (ABS)	0.5						
	Arsenic (As)	0.01						
	Chloride (Cl)	250.	9.	10.	7.	8.	8.	8.
	Copper (Cu)	1.						
	Carbon Chloroform Extract	0.2						
	Cyanide (CN)	0.01						
	Fluoride (F)	(See Note)						
	Iron (Fe)	0.3	0.06	0.10	0.04	0.02	0.06	0.06
	Manganese (Mn)	0.05						
	Nitrate (NO_3)	45.	trace	0.10	trace	trace	trace	0.10
	Phenols	0.001						
	Sulfate (SO_4)	250.	81.6	96.0	52.8	62.4	72.0	120.
	Total Dissolved Solids	500.	263.	305.	226.	219.	254.	321.
	Zinc (Zn)	5.						
Mandatory	Arsenic (As)	0.05						
	Barium (Ba)	1.0						
	Cadmium (Od)	0.01						
	Chromium (Hexavalent)(Cr^{+6})	0.05						
	Cyanide (CN)	0.2						
	Fluoride (F)	(See Note)						
	Lead (Pb)	0.05						
	Selenium (Se)	0.01						
	Silver (Ag)	0.05						
No Limits Given	Alkalinity ($CaCO_3$)		200.	184.	196.	192.	180.	192.
	Bicarbonate (HCO_3)		244.	224.	239.	234.	220.	223.
	Total Hardness ($CaCO_3$)		260.	252.	252.	228.	240.	288.
	Calcium (Ca)		54.4	52.8	49.6	49.6	52.8	57.6
	Magnesium (Mg)		30.2	29.2	30.2	25.3	25.3	35.0
	Sodium (Na)							
	Sodium and Potassium (Na+K)		17.29	21.16	5.89	18.51	12.04	18.48
	pH		7.75	7.7	7.78	7.76	7.82	7.93
	Carbonate (CO_3)		0	0	0	0	0	0

Source: Las Vegas Valley Water District

Note:

The Control limits for fluoride are described in the standards as follows:

Fluoride. When fluoride is naturally present in drinking water, the concentration should not average more than the appropriate upper limit in the tabulation below. Presence of fluoride in average concentrations greater than two times the optimum values in the tabulation below shall constitute grounds for rejection of the supply.

Where fluoridation (supplementation of fluoride in drinking water) is practiced, the average fluoride concentration shall be kept within the upper and lower control limits in the tabulation below:

Annual Average Of Maximum Daily Air Temperatures[1]	Recommended Control Limits Fluoride Concentrations in mg/l		
	Lower	Optimum	Upper
50.0-53.7	0.9	1.2	1.7
53.8-58.3	0.8	1.1	1.5
58.4-63.8	0.8	1.0	1.3
63.9-70.6	0.7	0.9	1.2
70.7-79.2	0.7	0.8	1.0
79.3-90.5	0.6	0.7	0.8

1. Based on temperature data obtained for a minimum of five years.

Nevada will also receive full credit for the flows of Las Vegas Wash entering Lake Mead if certain water quality standards are met. For every acre foot of acceptable quality water returned to Lake Mead via Las Vegas Wash, Nevada would be allowed to divert an extra acre foot of water from the mainstem of the Colorado River.

The quality of water in the mainstem of the lower Colorado River, with some treatment, is acceptable for drinking water purposes although some of its constituents are marginal. Table II-6 shows chemical analyses of Lake Mead water. The Colorado River Commission recently dedicated the Alfred M. Smith Water Treatment Facility. This 200 mgd treatment plant will filter all southern Nevada Water Project water at a site near Saddle Island. In addition to filtration, the plant also will provide taste, odor and pH control, and will chlorinate the water. It will not soften the water nor will it reduce the total dissolved solids or sulfates.

In general, the quality of Colorado River mainstem water deteriorates as it moves downstream. Thus, the quality of the water available below Davis Dam is not as good as that available in Lake Mead. There is a definite trend in the mainstem of the lower Colorado River toward increased concentrations of dissolved solids, sulfates, and hardness over a period of time.(16) Some researchers predict increases above today's levels as high as 50 percent by the turn of the century. Even if that much increase results, the mainstem of the lower Colorado River will be an acceptable source of potable water though it may display the bad affects of any water which has high concentrations of dissolved solids and sulfates.

Considerable research has been conducted in an effort to increase the yield of the Colorado River system. Included are cloud seeding programs, elimination of phreatophytes, and reservoir evaporation control. In time it is believed that

TABLE II–6

CHEMICAL ANALYSIS OF LAKE MEAD WATER

Concentrations, mg/l (except pH)

	Constituent	USPHS & Nevada Standards	24-yr Avg. Lake Mead Diversion at Boulder City Intake 1935-1958*	24-yr Avg. Lake Mead Diversion at Boulder City Intake 1941-1964**	BMI Pipeline at Booster Station No. 2 Feb. 1967
Recommended	Alkyl Benzene Sulfonate (ABS)	0.5			
	Arsenic	0.01			
	Chloride (Cl)	250.0	75	75	91
	Copper (Cu)	1			
	Carbon Chloroform Extract (CCE)	0.2			
	Cyanide (CN)	0.01			
	Fluoride (F)	(See Table II-4)	1		
	Iron (Fe)	0.3			0.03
	Manganese (Mn)	0.05			
	Nitrate (NO_3)	45.0	2		4.25
	Phenols	0.001			
	Sulfate (SO_4)	250	288	288	312
	Total Dissolved Solids	500	688	684	742
	Zinc (Zn)	5			
Mandatory	Arsenic (As)	0.05			
	Barium (Ba)	1.0			
	Cadmium (Cd)	0.01			
	Chromium (Hexavalent) (Cr^{+6})	0.05			
	Cyanide (CN)	0.2			
	Fluoride (F)	(See Table II-4)	1		
	Lead (Pb)	0.05			
	Selenium (Se)	0.01			
	Silver (Ag)	0.05			
No Limits Given	Alkalinity ($CaCO_3$)				122
	Bicarbonate (HCO_3)		186	161	149
	Carbonate (CO_3)				0
	Total Hardness ($CaCO_3$)		328		336
	Calcium (Ca)		92	91	84.8
	Magnesium (Mg)		30	26	30.08
	Sodium (Na)		92	91	111.64
	Sodium and Potassium (Na+K)		96		8.07
	pH				

Source * Report on SNWP, Nevada Appendices Vol II August 1963 by U. S. Bureau of Reclamation
** Quality of water Colorado River Basin, Progress Report No. 3 January 1967 by U. S. Dept. of Interior

these programs plus others will increase the amount of water available from the mainstem of the Colorado River. However, the increase probably will not bring the amount of water available from the mainstem of the Colorado River substantially above the allocated river flow (15 million acre feet per year) since the average flow in the river has been below this amount for many years. If insufficient mainstem water is available for release, as determined by the Secretary of the Interior, to satisfy annual consumptive use of 7,500,000 acre feet in the States of Arizona, California and Nevada, then the Secretary may apportion the amount remaining available for consumptive use in such manner as is consistent with the Boulder Canyon Project Act as interpreted by the opinion of the Supreme Court.

For the purposes of this study, it has been assumed that Nevada will be able to divert 300,000 acre feet per year from the mainstem of the Colorado River throughout the length of the study period. Outflow of acceptable quality from Las Vegas Wash and perhaps from other water courses will enable this amount to be increased in an amount equal to the outflow.

2.02(c)3 Reclaimed Waste Water. A comprehensive study (8) was recently completed to provide community guidance in the disposal of waste water originating in Las Vegas Valley. Several plans and alternatives within plans were presented in that study. The plans fell into four basic categories: ground-water recharge, exportation to the Colorado River system, direct reuse as a potable water supply, and exportation to a dry lake or valley. Reclaimed wastewater would be available for use as a potable water supply through the vehicle of an increased ground-water resource in the first instance. The second group of plans foresees the reclaimed waste water being available from Lake Mead on an exchange basis. The third plan was based on additional treatment of the effluent at the water treatment plant for the SNWP located alongside Lake Mead. No attempt was made in that study to return the waste water to the Las Vegas Valley in the fourth group of plans. However, the study proposed consideration of the fourth category only until the effluent is needed elsewhere for municipal and industrial purposes.

Subsequent to the publication of that report, another plan has been proposed to the community. This plan employs distillation of the effluent. The distillation would occur at a huge steam-generating station to be built near Las Vegas. No costs have yet been published for this plan.

The report emphasized the economic and engineering feasibility of reclaiming waste water for later potable water purposes. The estimated cost of making treated waste water available to the Las Vegas area at a hydraulic grade line high enough to serve most of the area is about $130 per acre foot at current prices.

Whether the waste water is allowed to recharge the ground-water basin, allowed to enter the Colorado River system, or transported directly to the potable water distribution system is immaterial for the purposes of this study, as long as at least one of these methods is capable of producing an acceptable quality product at a price less than the cost of importing water from outside the area.

It has been assumed that treated waste water, to the extent of 30 percent of the demand, will be available at a reasonable cost. Further, it has been assumed that these waste waters will be generated at a constant rate of flow throughout the year (an assumption that closely agrees with actual experience at the Las Vegas and Clark County Sanitation District treatment plants).

Year	Gross Water Demand AcFt/Yr	Ground Water AcFt/Yr	Lake Mead AcFt/Yr	Reclaimed Waste Water* AcFt/Yr	Total AcFt/Yr	Surplus or (Deficiency) AcFt/Yr
**						
1970	140,000					
1980	270,000	50,000	260,000	81,000	391,000	121,000
1990	392,000	50,000	258,000	118,000	426,000	34,000
2000	566,000	50,000	266,000	170,000	486,000	(80,000)
2010	662,000	50,000	281,000	199,000	530,000	(132,000)
2020	774,000	50,000	281,000	232,000	563,000	(211,000)
***						
1970	140,000					
1980	164,000	50,000	360,000	49,000	359,000	195,000
1990	249,000	50,000	258,000	75,000	383,000	134,000
2000	352,000	50,000	266,000	106,000	422,000	70,000
2010	490,000	50,000	281,000	147,000	478,000	(12,000)
2020	660,000	50,000	281,000	198,000	529,000	(131,000)

*Reclaimed waste water assumed to be 30% of gross water demand.
** Based on high growth rate.
*** Based on low growth rate.

TABLE II–7

WATER SUPPLY AND DEMAND IN LAS VEGAS METROPOLITAN SUBAREA

2.02(c)4 Water deficiency. Future water surpluses and deficiencies are given in Table II-7 and are plotted in Figure II-2. It can be seen from this figure that the Las Vegas Metropolitan subarea will commence having a water shortage in 1993 if the population reaches the high projection and in 2008 if it reaches the low projection.

2.03 FORT MOJAVE SUBAREA

2.03(a) Present and Future Population

The present permanent population of this subarea has been estimated at 50 people. There are existing nearby communities in which the operating personnel for the stream-generating station can live so these people alone will not provide the impetus required to start a community development in Fort Mojave. The future population is dependent to a large extent on the success of developers to seriously promote this subarea as a resort and retirement community. For this reason, it is believed that this subarea will either develop into a medium size urban area or not develop at all. The projected range in possible populations, either 100 or 60,000 for the subarea in 2020, as given in Table II-2, reflects this belief. The most probable population in 2020 is projected to be 50,000.

2.03(b) Present and Future Water Requirements

As with the population projections previously described, it is difficult to make a reasonable estimate of future water requirements in the Fort Mojave subarea, except for the demands of the Southern California Edison Company's steam-generating station. The Edison Company plant is expected to utilize 15,000 acre feet in 1971; 30,000 acre feet per year from 1972 to 1985; a steadily declining amount varying between 30,000 acre feet in 1985 to 15,000 acre feet in 2000; 15,000 acre feet per year from 2000 to 2006; and nothing after 2006. Table II-5 summarizes these demands.

The other water usage in this subarea is very small at this time, but will increase markedly as the various developments planned to be constructed along and near the river materialize. The Colorado River Commission has prepared a master plan of development for the Fort Mojave subarea. Most of the land already is under conditional sales contracts with specific water allocations from the mainstem of the Colorado River. The water requirements for Indian-owned land and land owned by U. S. Bureau of Reclamation have been included with those for other government purposes in the LMNRA. The following is a tabulation of the anticipated water allocations from Nevada's 300,000 acre foot allotment of the mainstem of the Colorado River which will be distributed outside of the Las Vegas Metropolitan Subarea:

Developer or Type of Land Use	Water Allocation or Estimate Ac Ft/yr
So. California Edison	Varies 0 to 30,000
Beaumont and Associates	11,000
Colorado River Prop.	1,200
Rio Alto Vista	380
Konig	400
Ft. Mojave Indians and National Recreation Area	6,000
Miscellaneous Small Users	20
Total Use from Colorado River excluding SCECo. and Las Vegas Metropolitan Subarea	19,000 Ac. Ft/yr

It is only conjecture when this water demand will be reached. For the purposes of this report it has been assumed to be reached early enough so that none of the allocation for Fort Mojave can be made available to other Nevada users of Colorado River water after the critical time of 1993.

2.03(c) Water Supply

The principal sources of water for the Fort Mojave subarea are the allocations from the mainstem of the Colorado River. These allocations total 13,000 acre feet per year for the developments, a varying amount up to 30,000 acre feet per year for the steam plant, and an undetermined portion of a 6,000 acre foot per year allocation for federally-owned land. After 2006 the Edison Company allocation is reduced to zero, and the subarea will have to rely upon only 13,000 acre feet per year from the mainstem of the Colorado River.

The ground-water supply is difficult to estimate because of the lack of information about it. The subarea lies in the southern portion of Colorado River Valley. The movement of surface and ground water in this valley is eastward to the Colorado River. Rush and Huxel (9) believe that the estimated annual recharge of about 200 acre feet could be captured if wells were drilled and pumped along the west bank of the river. The amount of water stored in the top 100 feet of wetted valley fill in this valley is estimated to be about 1 million acre feet.

Rush (10) estimates that the consumptive use by phreatophytes on approximately 2,600 acres in the southern portion of the Fort Mojave subarea is at least 5,000 acre feet. If the consumptive use by native vegetation were eliminated through eradication of the phreatophytes then the 5,000 acre feet of ground water presently being consumed by the plants would be available for use by future developments without causing any additional reduction in Colorado River flow.

As in other areas reclaimed waste water is a possible source of future water supply.

2.03(d) Water Balance

It is believed that water will prove to be one of the limiting factors to growth in the Fort Mojave subarea. Therefore, this subarea cannot be relied upon to export water to other subareas. Because of the controls that can be exerted by the CRC and the State Engineer, it is further believed that only as much land as can be supplied with Colorado River water, ground water, and reclaimed waste water will be sold for development. Therefore, it is concluded that this subarea is one with neither a surplus or a deficiency in water.

2.04 LAKE MEAD NATIONAL RECREATION AREA

2.04(a) Present and Future Population

The population of this area consists overwhelmingly of transient visitors. Visitor days amounted to 5.75 million in 1969. There are about 200 United States government and private concessionaire employees working in the park. About half of these live in the park. This number increases in the summer. Finally in all, there are about 150 lessees of cabins, but they are not continuous residents.

Lake Mead by 2020 can be envisioned as one of America's very important recreational centers. Steadily lengthening vacations and rising levels of personal income should result in a marked increase in the number of visitor days that will be spent in the park. Also a larger proportion of the visiting population will stay a longer time as more trailer parks are developed. By 2020 a five-or six-fold expansion of park population seems most probable.

2.04(b) Present and Future Water Requirements

During FY 1970, water consumption amounted to about 1,650 acre feet inside the park. Of this amount, it is estimated that 80 percent was used for irrigation purposes and 20 percent was used for domestic purposes.

With a five-or six-fold increase in visitor days by the year 2020, the water requirement at that time could be as much as 10,000 acre feet per year. Some of this, of course, would be supplied from Arizona's entitlement (say one third). The result is that an annual requirement of about 6,700 acre feet per year must come from Nevada's entitlement, from ground water, and from reclaimed waste water.

2.04(c) Water Supply

By Decree, the federal government has a right to divert water from the mainstem of the Colorado River for use within Nevada. This federal right is for use on federally-owned land such as the LMNRA, Indian reservations, and separate USBR parcels in the Fort Mojave area. For the purposes of this study, it has been assumed that 6,000 acre feet per year from the mainstem of the Colorado River will be required for the federal lands including the LMNRA.

Ground water stored in adjacent to the park is believed to exist in large quantities, but the annual recharge is quite small. Little is actually known about the ground-water source in and near the park. The portion of the park south of Black Canyon is in the Colorado River Valley ground-water basin. This basin is described in the previous subsection.

Reclaimed waste water is another source of water for the park area. It does not appear feasible to discharge waste waters outside the drainage basins for Lakes Mead and Mojave. Consequently, relatively complete treatment of the waste water emanating from the park undoubtedly will be required in order to preserve the quality of these lakes. A credit for this return flow probably can be obtained.

2.04(d) Water Balance

There are so many intangibles associated with the water requirements for the LMNRA that it is impossible to predict whether or not a water shortage will occur by the year 2020. The calculations given above indicate that a balance may be reached between supply and demand, depending upon demands of Indian reservations and other federal lands and upon the ground water resource. For the purposes of this report, it has been assumed that the LMNRA is a subarea without a surplus or a deficiency in water.

2.05 MOAPA VALLEY SUBAREA

2.05(a) Present and Future Population

The present population of Moapa Valley subarea has been estimated at 2,200 persons. This includes the communities of Overton, Logandale, Glendale, and Moapa and the adjoining countryside. The Moapa Valley is close enough to Las Vegas to be considered a future bedroom community for Las Vegas. The valley is adjacent to the resorts of Lake Mead and Valley of Fire. It is cut by Interstate 15 which provides easy access to the Las Vegas area.

Without artificial stimuli created by an overt attempt to disperse population throughout southern Nevada, the population may reach a high of 50,000 persons in 2020. The future predictions concerning this subarea's population growth are tabulated in Table II-2. The probable 2020 population is estimated to be 20,000.

2.05(b) Present and Future Water Requirements

The estimated present water use in the Moapa Valley subarea is presented in tabulated form below:

Use	Present Quantity Used Ac Ft./Yr.
Domestic	1,100
Industrial	6,500
Agricultural	20,000
TOTAL	27,600

As the Las Vegas Metropolitan subarea grows it is supposed that the Moapa Valley subarea would increase in population and become a suburban community of 20,000 population in year 2020. Assuming a per capita consumption at 400 gpcd the domestic demand in 2020 would be 9,000 acre feet per year. The industrial water use has been assumed the same in 2020 since additional cooling water for Nevada Power Company's steam generating station it is believed will come from outside the valley. Agricultural water use may have to decrease as domestic use increases in the future.

2.05(c) Water Supply

The Muddy River derives almost all of its flow from numerous springs a short distance northwest of the town of Moapa. The quality of water at the springs is fair but the quality deteriorates as the water progresses downstream to Lake Mead. The quantity of water in the Muddy River just downstream of the springs is almost constant at about 46.5 cfs (34,000 acre feet/year). Much of this water is being used for crop irrigation purposes and a small amount (approximately 1 cfs) is being used for domestic purposes.

The ground-water basin in the Muddy River subarea is recharged from the springs mentioned above. The amount of water stored in the upper 100 feet of saturated valley fill is estimated to be about 800,000 acre feet. The quality of water found in wells in this area is poor. With groundwater of poor quality, it is probable that future water development for municipal and industrial purposes will be from the springs rather than from wells.

Without long term storage, the amount of spring water that could be used for municipal and industrial purposes is about 18,000 acre feet per year (since maximum day demand is 1.88 times average day demand). Irrigation rights will have to be converted to domestic rights in order to achieve this usage. It is probable that some storage facilities would be constructed, however, so that about 25,000 acre feet per year could be used from the Muddy River.

Treatment of the spring water is indicated to reduce the concentration of fluoride (over 2 mg/l). All other known concentrations of chemicals are acceptable, although the dissolved solids are slightly in excess of the desired maximum. The water is classed as very hard. The spring water is warm at some locations (about 90 degrees F) but tends to cool during transportation downstream.

Reclaimed waste water is another source of water in this subarea. If 30 percent of the demand is available for reclaiming, the water supply would be increased by about 8,000 acre feet per year. The total available water would then be as follows:

Muddy River	25,000 acre feet per year
Reclaimed Waste Water	8,000 acre feet per year
TOTAL	33,000 acre feet per year

2.05(d) Water Balance Assumed

Considering the projected increased demands to be made upon the flows of the Muddy River, that water supply, while adequate to support projected future growth if agriculture is curtailed, is not available in sufficient quantity to be considered as a source for use in the Las Vegas Metropolitan subarea.

2.06 VIRGIN VALLEY SUBAREA

2.06(a) Present and Future Population

The present population of the Virgin Valley is 1,100. Mesquite, 700 population, is the largest community. It is devoted chiefly to roadside economic activity. Bunkerville, population 300, is an old, established community off the major highway. It now has no commercial activity and is simply a living place. The population of Bunkerville has been almost stationary for fifty years. The population of Mesquite has only increased about 400 in the last twenty years.

The economic prospects of the area would appear to lie in further development of tourism at Mesquite. Mesquite already has seven motels, a bar-casino, and a dozen restaurants and drive-ins. The area appears to be too far away, 80 miles to serve as an important commuter community for Las Vegas. Most probable population for 2020 is estimated at 10,000, as shown in Table II-2.

2.06(b) Present and Future Water Requirements

The estimated present use in the Virgin River subarea is presented below:

Use	Present Quantity Used Ac. Ft./Yr.
Domestic	550
Industrial	-
Agricultural	13,250
TOTAL	13,800

Based upon economic factors and the quality of the water of the Virgin River, the most probable population in year 2020 is estimated at 10,000. A population of 10,000 would require a domestic supply of about 4,500 acre feet per year. It is assumed that the 4,500 acre feet of water required for domestic use would be pumped from wells where it is possible to obtain water of a quality suitable for domestic use. Therefore, the expansion of population in the Virgin Valley would not severely curtail farming in the area. Agriculture along the Virgin River is not limited by the quantity of water but by its quality. Some expansion of agriculture along the Virgin River would be possible if phreatophyte control was practiced. As the quality of the Virgin River deteriorates larger amounts of water will be required with no increase in productivity. This process will be hastened if the proposed Dixie project is constructed near St. George. Utah and diverts a portion of the Virgin River flow.

2.06(c) Water Supply

2.06(c)1 Virgin River. , The Virgin River is an important resource to southeastern Nevada. It is large in quantity, but poor in quality. The Virgin River originates in Utah, flows through Arizona, and discharges into Lake Mead in Nevada. The flow in the river is extremely variable with annual amounts, as measured at Littlefield, Arizona, ranging between 78,000 and 400,000 acre feet per year, and an average of 162,200 acre feet per year, since 1930. Monthly and daily fluctuations are, of course, considerably more variable. If the proposed Dixie Project is constructed near St. George, Utah, the expected effects in Nevada are a reduction in flow of more than 30 percent, some stabilization of flow rates, and a deterioration in water quality.

Only a small portion of the annual flow in the Nevada section of the river is consumptively used (about 14,000 acre feet per year). It has been estimated that about 80,000 acre feet per year as surface flow enters Lake Mead from the Virgin River. Evapotranspiration losses and ground-water recharge account for most of the difference.

In order to develop a river of this type to produce large quantities of water for municipal and industrial purposes, some storage along the river is required. Oral communication with a representative of the U.S. Bureau of Reclamation has indicated that their studies show there is not a feasible dam site along the portion of the river in Nevada.

A second alternative for storage is, of course, Lake Mead. Since the United States Supreme Court has held that the Lower Basin States are entitled to exclusive use of the tributaries of the Colorado River within each state, the possibility exists than an entitlement to Nevada could be obtained for the surface and subsurface inflow to the mainstem of the Colorado River from the Virgin River Valley. If this is achieved, Nevada's entitlement to water from the Colorado River mainstem would increase markedly. Once in Lake Mead, the water presumably could be extracted at any point along the lake shore or downstream of Hoover Dam. It is apparent that Nevada should vigorously pursue a tri-state compact for use of water in the Virgin River, and that it should investigate the possibility that the introduction of Virgin River water into Lake Mead creates an entitlement by the State to increase diversions of water from the mainstem of the Colorado River over and above the 300,000 acre feet apportioned to Nevada.

While large in quantity, the Virgin River is very poor in quality. Table II-8 shows a time-weighted average of chemical characteristics of flows in the Virgin River during water year 1967-68. The river flow grossly exceeds the recommended maximum concentrations of sulfates, chlorides, and dissolved solids and is very hard. Also, it carries a large load of suspended solids. Without very expensive treatment, the river water is not suitable for

TABLE II–8

CHEMICAL ANALYSIS OF VIRGIN RIVER WATER

Concentrations mg/l (except pH)

	Constituent	USPHS & Nev. Standards	Virgin River
Recommended	Alkyl Benzene Sulfonate (ABS)	0.5	
	Arsenic (As)	0.01	
	Chloride (Cl)	250	305.0
	Copper (Cu)	1	
	Carbon Chloroform Extract (CCE)	0.2	
	Cyanide (CN)	0.01	
	Fluoride(F)	(See Table II-4)	
	Iron (Fe)	0.3	
	Manganese (Mn)	0.05	
	Nitrate (NO_3)	45	
	Phenols	0.001	
	Sulfate (SO_4)	250	796.0
	Total Dissolved Solids	500	1850.0
	Zinc (Zn)	5	
Mandatory	Arsenic (As)	0.05	
	Barium (Ba)	1.0	
	Cadmium (Cd)	0.01	
	Chromium (Hexavalent) (Cr^{+6})	0.05	
	Cyanide (CN)	0.2	
	Fluoride (F)	(See Table II-4)	
	Lead (Pb)	0.05	
	Selenium (Se)	0.01	
	Silver (Ag)	0.05	
No Limits Given	Alkalinity ($CaCO_3$)		
	Bicarbonate (HCO_3)		289.0
	Total Hardness ($CaCO_3$)		1020.0
	Calcium (Ca)		
	Magnesium (Mg)		
	Sodium (Na)		
	Sodium and Potassium (Na+K)		7.9
	pH		
	Carbonate ($C0_3$)		

Source: USGS Water Resources Data for Nevada - 1968
Location: 0.4 mile downstream from Beaver Dam Wash
Time Weighted Average: October 1967 to September 1968

municipal and industrial purposes. However, when blended in a large body of water, such as Lake Mead, the water in the Virgin River is acceptable for these purposes.

2.06(c)2 Ground Water. Ground water in the Nevada portion of the Virgin Valley is abundant and better in, quality than the river water. This unconfined (water-table) ground-water basin drains into the Virgin River. It is comparatively close to the ground surface (about 50 feet deep) near the river and progressively deeper farther from the river. It has been estimated that about 3 million acre feet of water are stored in the upper 100 feet of saturated valley fill.

Ground-water recharge is estimated to total about 10,500 acre feet per year in the lower Virgin Valley from precipitation and subsurface inflow. During periods of high river stages, the ground-water basin is recharged an unknown amount but it may exceed recharge from other sources.

Subsurface outflow to Lake Mead could be as much as 40,000 acre feet per year. This amount is in addition to the 80,000 acre feet per year of surface flow into Lake Mead.

The quality of ground water varies from good to totally unacceptable without treatment. Generally, ground water is of better quality if extracted from wells located away from the Virgin River flood plain. In almost all wells, the water is classed as very hard (more than 180 mg/l). The principle constituents that make the water unacceptable are chlorides, sulfates, and dissolved solids. Fluorides and nitrates do not appear to be in concentrations high enough to cause problems if the ground water is used for municipal and industrial purposes. There is some evidence that the quality of ground water deteriorates as the pumping rate increases.

In summary, the Virgin River Valley ground-water basin is largely an unknown if considered for interbasin transfer of water or local municipal and industrial use. There are enough wells with unacceptable water being pumped to make the basin a dubious source of large quantities of ground water.

2.06(c)3 Reclaimed Waste Water. When substantial municipal and industrial development occurs it may be feasible to consider the use of reclaimed waste water for potable water purposes. Until then, waste water is of insignificant quantity to be feasible for further municipal and industrial use.

2.06(d) Water Surplus

The lower Virgin Valley within Nevada has a surplus of poor quality water. At the present time about 120,000 acre feet per year is entering Lake Mead, either as surface or subsurface flow. Even if the proposed Dixie project is constructed, it is estimated that a surplus of about 60,000 acre feet per year will occur in this subarea. Possible domestic development within the subarea could reduce the surplus by another 4,500 acre feet per year.

2.07 PAHRUMP VALLEY SUBAREA

2.07(a) Present and Future Population

The present population of Pahrump Valley is probably about 1,200 with nearly 1,000 in the town of Pahrump. The town is a development of the last two decades. It is largely a bedroom community for workers at the Nevada Test Site.

The economic prospects of the community appear to lie in its further development as a commuter community and also as a second home area. Sale of lots is being actively promoted by real estate firms and great growth of population is expected by many. Although it is not on any major highways, it may be able to develop some tourist-casino activity since it is near Death Valley and actually near the California-Nevada state line.

Most probable population of 2020 is thought to be 10,000. If the valley is selected as a site for large-scale promotional effort, the population could reach 100,000 by the year 2020.

2.07(b) Present and Future Water Requirements

In 1968 about 48,000 acre feet of water was used to irrigate 11,000 acres of cultivated land and to supply domestic water to less than 1,000 people. The most probable population for the Pahrump Valley in year 2020 is 10,000 which would require about 4,500 acre feet per year of water supply. Since the water rights issued already exceed the annual recharge, permits are not being granted to appropriate ground water for irrigation purposes.

2.07(c) Water Supply

The sources of information for this subsection were: U.S. Bureau of Reclamation Reconnaissance Investigations Report (11), Nevada Water Resources bulletin (6), U.S. Geological Survey Water-Supply Paper (12), and unpublished reports of the Nevada State Engineer. The data contained herein are considered fairly reliable, but of course are subject to change as more information is developed.

The only water supply of any importance in Pahrump

Valley is the ground water basin underlying the Valley. The ground water basin is composed of a near surface water table zone and several lower zones confined in the valley fill similar to those found in the Las Vegas Valley ground water basin. The main source of supply in Pahrump Valley is from the lower confined zones. Underlying the valley fill are carbonate rocks into which no wells have been drilled. Ground water in the carbonate rocks is not considered further as a source for the purposes of this report.

Annual recharge to the ground-water basin is primarily from the Spring Mountains and has been estimated to be about 22,000 acre feet per year with a perennial yield of 12,000 acre feet per year. The volume of stored ground water in the top 100 feet of saturated valley fill has been estimated to be about 6 million acre feet, of which 70 percent or 4.2 million acre feet has been assumed available for export. The water level in wells is shallow (few to several tens of feet) and is dropping at the rate of about 2 feet per year in areas of concentrated pumpage. The pumping levels of fifteen selected wells ranges from 60 feet to 218 feet with an average of 122 feet. Discharges range from 275 gpm to 1,225 gpm with an average of 730 gpm.

Discharge from the ground-water basin is from subsurface flow, springs, and pumping from about 100 wells. Discharge from wells and springs is currently occurring at a rate of about 49,000 acre feet per year, of which about 1,000 is leaving through springs. Subsurface outflow is estimated at 10,000 acre feet per year. The perennial yield is 12,000 acre feet per year.

Since 1965, the State Engineer has not issued permits to appropriate ground water to irrigate land not, at that time, already covered under an existing water right. Subsequent to that time, permits have been issued for uses other than irrigation and irrigation permits have been issued supplemental to existing irrigation water rights as long as no expansion of acreage occurred. On the first day of June, 1970, an order was issued by the State Engineer which in effect eliminates the granting of any irrigation permits, including supplemental irrigation permits, in the designated area of the Pahrump Artesian Basin.

The quality of ground water generally is good with chemical analyses of water from most wells meeting drinking water standards. As with most waters in southern Nevada, the ground water in this basin is very hard. The chemical analysis of selected wells in the valley is given in Table II-9.

Reclaimed waste water would be considered a source of supply if the valley becomes urbanized. Until such time as this occurs, it is not considered feasible to reclaim waste water on any scale.

2.07(d) Water Balance

As was seen, the Pahrump Valley ground water basin is in a state of overdraft with withdrawals being about four times the perennial yield. The overdraft will continue if owners of ground water rights exercise these rights. However, the basin contains a large amount of stored ground water from which to draw.

If the ground water basin is not used as a source of water for interbasin transfer, and if the population in the valley is not deliberately increased as part of a dispersion plan, the ground water resource will adequately furnish the projected population with potable water. The ground water basin is a definite source of water for interbasin transfer since the quality is good and the quantity large.

2.08 AMARGOSA DESERT SUBAREA

2.08(a) Present and Future Population

Present population of the Amargosa Desert is 1,500 of whom 1,200 live in the town of Beatty. This community is engaged principally in roadside activity as it is on U.S. Highway 95 which runs between Las Vegas and Reno. The proximity of Death Valley is also a stimulant to the tourist business. Beatty also serves as a bedroom community for some workers at the Nevada Test Site.

Potential growth appears to rest on further expansion of tourist activity. Mining employs only a few people and is in decline. Agriculture only involves a few farms and also has been dwindling except in the Ash Meadows area.

It seems unlikely that any strong growth in economic base activity will occur in the Amargosa Desert. Its distance, nearly 125 miles from Las Vegas, also limits its attractiveness as a commuter community. Most probable population for 2020 is estimated at 5,000.

2.08(b) Present and Future Water Requirements

Water requirements in the Amargosa Desert have varied dramatically in the last decade in relation to the numerous attempts at farming the area. The domestic use in Amargosa is presently about 750 acre feet per year. The amount used for industry is assumed negligible and the agricultural water requirements, although varying, have always been less than the available annual yield of the springs in the valley. In recent years the demand for agricultural water has fallen because soil problems have arisen.

The future most probable population of Amargosa Desert has been estimated at 5,000. Assuming per capita water use at 400 gpcd, the domestic requirement in year 2020 would be about 2,200 acre feet per year.

	Constituent	USPHS & Nev. Standards	Concentrations mg/l (except pH) Wells					
			19-53-9bb	19-53-21aa	20-53-3cd	21-54-16ad	21-54-21bc	22-54-24dc
Recommended	Alkyl Benzene Sulfonate (ABS)	0.5						
	Arsenic (As)	0.01						
	Chloride (Cl)	250	12.0	6.0	3.8	3.0	2.8	6.0
	Copper (Cu)	1						
	Carbon Chloroform Extract (CCE)	0.2						
	Cyanide (CN)	0.01						
	Fluoride (F)	(See Table II-4)	0.3	0.1	0.2	0.5	0.2	0.4
	Iron (Fe)	0.3						
	Manganese (Mn)	0.05						
	Nitrate (NO_3)	45	2.4	2.0	1.7	0.6	0.9	0.5
	Phenols	0.001						
	Sulfate (SO_4)	250	36.0	20.0	26.0	47.0	48.0	55.0
	Total Dissolved Solids	500	314.0	264.0	249.0	260.0	234.0	324.0
	Zinc (Zn)	5						
Mandatory	Arsenic (As)	0.05						
	Barium (Ba)	1.0						
	Cadmium (Cd)	0.01						
	Chromium (Hexavalent) (CR^{+6})	0.05						
	Cyanide (CN)	0.2						
	Fluoride (F)	(See Table II-4)						
	Lead (Pb)	0.05						
	Selenium (Se)	0.01						
	Silver (Ag)	0.05						
No Limits Given	Alkalinity ($CaCO_3$)							
	Bicarbonate (HCO_3)		280.0	269.0	242.0	224.0	186.0	281.0
	Total Hardness ($CaCO_3$)		222.0	232.0	215.0	223.0	188.0	-
	Calcium (Ca)		46.0	47.0	50.0	53.0	36.0	69.0
	Magnesium (Mg)		26.0	28.0	22.0	22.0	24.0	26.0
	Sodium (Na)		28.0	7.5	6.9	7.1	9.2	6.9
	Sodium and Potassium (Na+K)		32.0	9.1	9.1	7.9	10.7	7.3
	pH		7.8	7.9	8.1	7.8	7.7	8.0
	Carbonate (CO_3)							

Source: Geological Survey Water Supply Paper 1832 Page 141.

TABLE II–9

CHEMICAL ANALYSIS OF WATER SAMPLES FROM PAHRUMP

2.08(c) Water Supply

The data contained in this subsection have been taken from a State of Nevada Reconnaissance Series Report (13) , a U.S. Bureau of Reclamation reconnaissance investigations report (14) , and unpublished reports of the Nevada State Engineer. The data should be considered preliminary only and subject to substantial change as more information is obtained.

The water supply in the Amargosa Desert comes partially from the Amargosa River, partially from springs, and mostly from the ground water basin. The river has an average flow near Beatty of less than 1,000 acre feet per year. Most of this flow occurs after periods of heavy precipitation and the river is dry at other times. The river has been disregarded as a source of water for the purposes of this report.

Springs are present in the Ash Meadows area of Amargosa Desert. The annual discharge from these springs is estimated to be about 17,000 acre feet, at a relatively uniform rate.

Ground water occurs in the Amargosa Desert in valley fill and underlying carbonate rocks. The annual recharge is estimated at 24,000 acre feet, of which 17,000 acre feet surfaces as springs. The total volume of ground water stored in the top 100 feet of saturated valley fill is estimated to be 2,700,000 acre feet.

Natural discharge from the basin is considered to be about 24,000 acre feet per year, mostly through evapotranspiration.

The depth to water in wells varies throughout the desert, but averages about 100 feet. The average depth of wells is about 300 feet and discharges average about 500 gpm. Some of the newer wells discharge in excess of 2,000 gpm. The static water level has dropped an average of four feet in areas of concentrated pumping since the mid 1950's.

The perennial yield of the Amargosa Desert ground water basin has been considered to be 24,000 acre feet per year assuming outflow from the springs is included.

The quality of water in the Amargosa Desert is generally acceptable for municipal and industrial purposes except for its high fluoride content (in excess of 1.5 mg/l in most wells). Some well water shows total solids in excess of the recommended maximum of 500 mg/l, but not enough to be troublesome. Iron was discovered in some well waters in excess of the recommended maximum of 0.3 mg/l. Again the frequency of occurrence is low enough so that iron should not pose a problem for large scale development.

A summary of selected chemical analyses of water taken from wells in Amargosa Desert is given in Table II-10.

Reclaimed waste water could be considered a source of supply if the desert becomes urbanized. Until that time, it is not considered feasible to reclaim waste water.

2.08(d) Water Surplus

Today the inhabitants of Amargosa have a surplus of water based upon present use and annual yield of the springs in the area and a large volume of ground water in storage. Water stored in the upper 100 feet of the ground water basin has been assumed to be available for export along with most of the annual recharge. If this water were to be exported, it would be necessary to purchase agricultural land and associated water rights in the area. Water for domestic use would of course be available for the present and future residents in Amargosa.

2.09 RAILROAD VALLEY SUBAREA

2.09(a) Present and Future Population

The present population of Railroad Valley is less than 100, consisting wholly of people on a few farms in the area. Very little increase in population growth and agricultural development is anticipated unless federally-controlled lands are made easily available for development. Existing farms may continue. Most likely population for 2020 is expected to still be 100.

TABLE II–10

CHEMICAL ANALYSIS OF WATER SAMPLES FROM AMARGOSA

	Constituent	USPHS & Nev. Standards	Concentrations mg/l (except pH)					
			Well 16-48-23da	Well 16-48-36aa	Well 16-49-35ba	Well 16-50-7ca	Spring 17-50-15aa	Spring 17-51-14cb
Recommended	Alkyl Benzene Sulfonate (ABS)	0.5						
	Arsenic (As)	0.01						
	Chloride (Cl)	250	31.9	10.6	58.5	33.7	24.8	70.9
	Copper (Cu)	1						
	Carbon Chloroform Extract (CCE)	0.2						
	Cyanide (CN)	0.01						
	Fluoride (F)	(See Table II-4)	2.05	0.22	3.80	4.20	1.65	2.50
	Iron (Fe)	0.3			0.03	0.88	0.16	
	Manganese (Mn)	0.05						
	Nitrate (NO_3)	45						
	Phenols	0.001						
	Sulfate (SO_4)	250	61.0	28.3	210.0	180.0	81.7	240.0
	Total Dissolved Solids	500	267.0	179.0	629.0	571.0	406.0	837.0
	Zinc (Zn)	5						
Mandatory	Arsenic (As)	0.05						
	Barium (Ba)	1.0						
	Cadmium (Cd)	0.01						
	Chromium (Hexavalent) (Cr^{+6})	0.05						
	Cyanide (CN)	0.2						
	Fluoride (F)	(See Table II-4)						
	Lead (Pb)	0.05						
	Selenium (Se)	0.01						
	Silver (Ag)	0.05						
No Limits Given	Alkalinity ($CaCO_3$)							
	Bicarbonate (HCO_3)		131.0	137.0	275.0	299.0	295.0	436.0
	Total Hardness ($CaCO_3$)		-	-	196.0	203.0	209.0	-
	Calcium (Ca)		26.0	17.6	69.6	56.8	56.0	55.2
	Magnesium (Mg)		5.8	1.7	11.9	8.1	12.0	30.2
	Sodium (Na)		69.0	46.5	127.0	130.0	77.7	210.0
	Sodium and Potassium (Na+K)		74.8	51.2	138.7	140.2	84.3	222.1
	pH		7.7	7.7	7.7	7.7	7.4	7.6
	Carbonate (CO_3)		0	0	0	0		0

Analyses by U.S. Bureau of Reclamation and U.S. Geologic Survey.

2.09(b) Present and Future Water Requirements

There are approximately 2,000 acres under irrigation in Railroad Valley and at 5 acre feet per acre per year this represents a use of 10,000 acre feet per year. The future water requirements for the purpose of this report has been assumed equal to the total of the existing certificated, permitted, and pending ground water rights of 27,000 acre feet per year.

2.09(c) Water Supply

The data contained in this subsection have been obtained from unpublished reports of the Nevada State Engineer. The data should be considered very preliminary and subject to substantial change as more information is developed.

The ground-water basin is estimated to have 7,000,000 acre feet of water in storage in the top 100 feet of saturated valley fill. The recharge and perennial yield are each estimated to be 52,000 acre feet per year. Static water levels in wells show a complete recovery each year so no overdraft is taking place. What little information is available concerning wells in the valley indicates that most are drilled to a depth of about 200 feet. Depth to static water averages about 80 feet and discharges as high as 5,000 gpm are recorded.

The quality of water extracted from six wells in Railroad Valley is good for municipal and industrial purposes. Table II-11 gives the results of chemical analyses made on water from those wells. The high concentrations of iron in two of the analyses undoubtedly were caused by corrosion on the

TABLE II–11

CHEMICAL ANALYSIS OF WATER SAMPLES FROM RAILROAD VALLEY

			Concentrations, mg/l (except pH)					
		USPHS & Nev.	Well Location					
	Constituent	Standards	5/55-27b	5/55-33b	5/55-34d	6/56-14c	6/56-23a	8/57-14a
Recommended	Alkyl Benzene Sulfonate (ABS)	0.5						
	Arsenic (As)	0.01						
	Chloride (Cl)	250.	14	6	11	2	2	8
	Copper (Cu)	1.						
	Carbon Chloroform Extract	0.2						
	Cyanide (CN)	0.01						
	Fluoride (F)	(See Table II-4)						
	Iron (Fe)	0.3	56	tr.	3.6	tr.	0	tr.
	Managanese (Mn)	0.05						
	Nitrate (NO_3)	45.	3	2	1	3	4	2
	Phenols	0.001						
	Sulfate (SO_4)	250.	45	21	40	3	8	25
	Total Dissolved Solids	500.	222	233	206	252	223	370
	Zinc (Zn)	5.						
Mandatory	Arsenic (As)	0.05						
	Barium (Ba)	1.0						
	Cadmium (Cd)	0.01						
	Chromium (Hexavalent)(Cr^{+6})	0.05						
	Cyanide (CN)	0.2						
	Fluoride (F)	(See Table II-4)						
	Lead (Pb)	0.05						
	Selenium (Se)	0.01						
	Silver (Ag)	0.05						
No Limits Given	Alkalinity ($CaCO_3$)		94	154	136	214	190	300
	Bicarbonate (HCO_3)		115	188	165	261	232	366
	Total Hardness ($CaCO_3$)		116	156	140	220	184	276
	Calcium (Ca)		30	37	93	54	46	72
	Magnesium (Mg)		10	16	56	20	17	23
	Sodium and Potassium (Na+K)		17	14	22	1	8	24
	pH		7.9	7.9	8.0	7.7	7.8	7.5
	Carbonate (CO_3)		0	0	0	0	0	0

SOURCE: Samples collected by Montgomery Engineers of Nevada and analyzed by Nevada State Division of Health

NOTE: High iron concentrations most probably caused by lengthy inactivity of well sampled.

well casing and inactivity of the pump.

With no urban development, reclaimed waste water cannot be considered a source of supply in Railroad Valley.

2.09(d) Water Surplus

The water surplus in Railroad Valley which has been assumed available for export is 25,000 acre feet per year of the annual recharge, and ground water in storage. The remaining 27,000 acre feet per year of the annual recharge has been assumed adequate for all development in Railroad Valley until year 2020.

2.10 PAHRANAGAT VALLEY SUBAREA

2.10(a) Present and Future Population

The present population of the Pahranagat Valley is 300 people most of whom live in the town of Alamo. Alamo's roadside activity is small.

The area is an attractive one, but due to its distance from Las Vegas, 100 miles, its potential as a commuter community appears very limited. Since the area is attractive and the importance of the highway as a north-south route will increase, more tourist activity should develop. Most likely population in the year 2020 is 2,500.

2.10(b) Present and Future Water Requirements

The 1963, and probably the present, water requirements of the Pahranagat Valley subarea are about 25,000 acre feet per year. Apparently agriculture is at its fullest so any increase in water requirement would have to come from municipal demands. Because of its less urbanized environment and because of the milder climate, it is estimated that the demand for municipal water will be only about 300 gpcd in the year 2020. For an estimated probable population of 2,500, the demand would be 840 acre feet per year in 2020. This is an insignificant increase over today's demand and should not affect the agricultural use of water in the valley.

2.10(c) Water Supply

This subsection has been prepared from information contained in a Nevada reconnaissance series report (15) and unpublished reports of the Nevada State Engineer. The data should be considered of reconnaissance grade only and subject to change when additional information is obtained.

The water supply in Pahranagat Valley comes mostly from springs located at the northern (upper) end of the valley. Some ground-water pumpage takes place to supplement the flow from springs.

Ground water occurs in valley fill and underlying carbonate rocks. The annual recharge to the ground-water basin is estimated at 25,000 acre feet, almost all of which is through carbonate rocks transmitting water from outside the drainage basin from sources northerly of the springs. As with other springs studied, the flow from the springs is relatively constant. The total volume of ground water stored in the upper 100 feet of saturated valley fill is estimated to be 2,200,000 acre feet.

Discharge from the ground-water basin is believed to occur in three ways: evapotranspiration, subsurface outflow through valley fill, and subsurface outflow through carbonate rocks. The amount of ground water lost by evapotranspiration is estimated to be about 25,000 acre feet per year. The loss from subsurface outflow through the valley fill is minor and through the rocks unknown.

The depth to water in the valley is quite shallow, water being at or near the surface in many locations. Most of the wells apparently are small since they are used for domestic and stock watering purposes. A few wells located north of Hiko are being used to irrigate crops. These wells are capable of discharging about 1,000 gpm each.

The perennial yield of the Pahranagat Valley ground-water basin has been estimated at 25,000 acre feet per year if the source of flow from the carbonate rocks to the north is not cut off.

The quality of ground water in Pahranagat Valley is best near the springs at the upper end of the valley and worst at the lower end. The water samples taken from the springs show chemical constituents that meet the Drinking Water Standards, whereas the water samples farther downstream generally exceed the limits of sulfates and dissolved solids. The limited information suggests that fluorides are not a problem. Table II-12 contains representative chemical analysis of ground water and spring water in Pahranagat Valley.

Reclaimed waste water cannot be considered a source of water in this subarea because of the paucity of people.

2.10(d) Water Surplus

Today inhabitants of the Pahranagat Valley live in balance with the water supply available to them. However, if Pahranagat is used as a source of water for the Las Vegas Metropolitan subarea, the annual spring discharge plus water in the top 100 feet of the ground water basin have been assumed available for export. In order to maintain a water balance in Pahranagat under these circumstances, it would be necessary to purchase all agricultural land and associated water rights. Water for domestic use would, of course, always be available for the residents of Pahranagat Valley.

TABLE II–12

CHEMICAL ANALYSIS OF WATER SAMPLES FROM PAHRANAGAT

	Constituent	USPHS & Nevada Standards	Concentrations, mg/l (except pH) Well Location: 4/60-14 Aug. 70[1]	6/61-2 Aug. 70[1]	Hiko Springs[2] June 44	Crystal Springs[2] April 63	Ash Spring[2] June 44	Alamo Town[2] Well/Sept. 44	Upper Pahranagat[2] Sept. 44	Lower Pahranagat[2] Sept. 44
Recommended	Alkyl Benzene Sulfonate (ABS)	0.5								
	Arsenic (As)	0.01								
	Chloride (Cl)	250.0	65	16	10.6	8.2	10.6	28.0	117.1	106.3
	Copper (Cu)	1.0								
	Carbon Chloroform Extract (CCE)	0.2								
	Cyanide (CN)	0.01								
	Fluoride (F)	(See Table II-4)								
	Iron (Fe)	0.3	tr.	0						
	Manganese (Mn)	0.05								
	Nitrate (NO_3)	45.0	53	6		1.2				
	Phenols	0.001								
	Sulfate (SO_4)	250.0	320	76	35.5	29.6	34.6	101.8	335.3	432.8
	Total Dissolved Solids	500.0	877	625	36.0		335.0	780	1240.0	1230.0
	Zinc (Zn)	5.								
Mandatory	Arsenic (As)	0.05								
	Barium (Ba)	1.0								
	Cadmium (Cd)	0.01								
	Chromium (Hexavalent)(Cr^{+6})	0.05								
	Cyanide (CN)	0.2								
	Fluoride (F)	(See Table II-4)				0.57				
	Lead (Pb)	0.5								
	Selenium (Se)	0.01								
	Silver (Ag)	0.05								
No Limits Given	Alkalinity ($CaCO_3$)		234	538	280.0	272.0	256.3	414.9	597.9	546.1
	Bicarbonate (CHO_3)		285	437				17.1	30.0	81.0
	Carbonate (CO_3)		0	0						
	Total Hardness ($CaCO_3$)		460	324	48.1	45.1	46.5	57.1	42.7	20.2
	Calcium (Ca)		93	64	23.1	23.5	19.3	14.0	72.6	26.9
	Magnesium (Mg)		56	40	29.9	23.0	29.9	146.0	298.9	469.0
	Sodium (Na)									
	Sodium and Potassium (Na+K)		111	64						
	pH		7.6	7.6						

SOURCE: 1. Samples collected by Montgomery Engineers of Nevada and analyzed by Nevada State Division of Health
2. Analyses taken from reference (15)

III PART 2 SUPPLEMENTAL WATER SOURCES WITHIN NEVADA

SUPPLEMENTAL WATER SOURCES WITHIN NEVADA

3.01 GENERAL

There are within the southern portion of Nevada several areas from which it may be possible to obtain a supplemental water supply to support the projected future growth of the Las Vegas Metropolitan subarea. The facilities required to collect and transport the water from these sources to the Las Vegas Metropolitan subarea and the costs associated therewith are the subject of this section.

A very important basic assumption underlying the intrastate water transfer plans is that they are expected to supply water for an interim period only. This period begins when the total water resources of the Las Vegas Valley, including ground water, recycled water and the allotment of Colorado River mainstem water are no longer sufficient to sustain future growth of the area. The period continues until water from a source outside the state becomes available for use in Las Vegas Valley. For the purpose of this study, it has been assumed that interstate transfer of water will be a reality by year 2020.

As discussed in subsection 2.02(c)4, the time at which the water demand is expected to exceed the total available resource, assuming that no intrastate water transfers or augmentation of the Colorado River mainstem occurs, is 1993 or 2008 for the high and low growth rates respectively.

There are five source areas which have been investigated for intrastate transfers: Pahrump Valley, Amargosa Desert, Railroad Valley, Pahranagat Valley, and the Virgin Valley. These sources have been selected as being generally representative of conditions to be encountered in southern Nevada and do not necessarily exhaust all possible areas from which it might be possible to obtain a supplemental water supply.

The water supply in these source subareas, with the exception of the Virgin Valley, is not apparent to the casual observer passing through Nevada for it does not manifest itself in wide rivers or beautiful lakes, nor is its presence suggested by vast expanses of green meadows and lush forests. Reference is of course, made to ground water which underlies much of the apparently dry and parched desert landscape of Nevada. This water has for centuries been accumulating in the valley fills and the carbonate rocks which characterize the valley floors in southern Nevada. These ground-water basins constitute a valuable natural resource and it may be possible to develop and put to beneficial use this resource in much the same manner that beneficial use has been made of other natural resources of Nevada.

The facilities required to develop this natural resource are discussed in this section along with the cost of transporting the water to the subarea of need.

3.01(a) Destination of Imported Water

Although the aqueducts discussed in this report have their beginnings scattered over the southern part of Nevada, southern California and the Pacific Northwest, they all have the same destination ... the Las Vegas Metropolitan subarea. This subarea alone in southern Nevada has exhibited the wherewithal to have established an economic base, and therefore, power to attract population to the area having a thirst that local sources alone may not be capable of quenching.

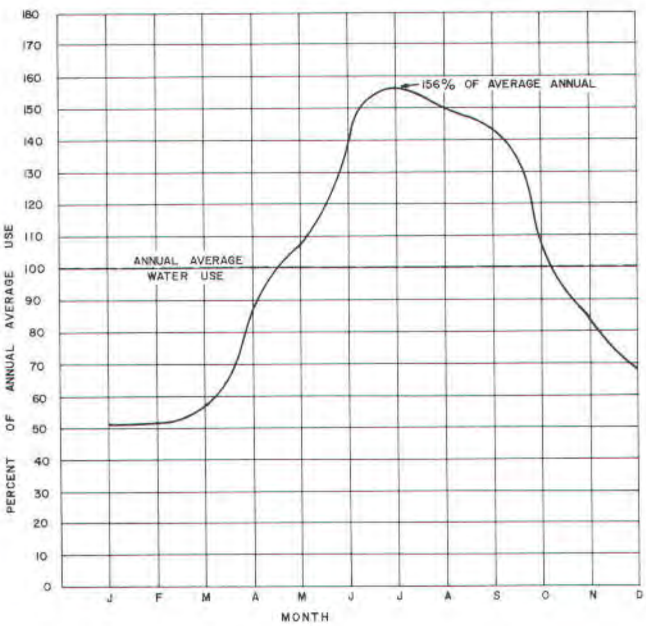
3.01(b) Required Aqueduct Capacity

Aqueduct facilities described in this section have been sized to supply the projected water deficit in the Las Vegas Metropolitan subarea in the year 2020 for both the high and low projected growth rate. The estimated annual delivery required in year 2020 is 211,000 acre feet and 131,000 acre feet for the high and low growth rates respectively as shown in Table II-7. Supply of this annual requirement at a uniform rate would result in transmission facilities sized respectively to convey flows of 290 or 180 cfs, every day of the year.

The variations in monthly water demands for Las Vegas are approximated by the records of monthly water use in the Las Vegas Valley Water District for 1968 and 1969. This water use is shown graphically in Figure III-1. The maximum day demand is 188 percent of the average daily

SUPPLEMENTAL WATER SOURCES WITHIN NEVADA

use. As indicated in that figure, water use in July is 156 percent of the average daily use, and water use during a four-month period, June through September, is approximately 150 percent of the average daily use. Design of aqueduct facilities to deliver water at 188 percent or even 156 percent of average daily use from a distance of 70 to 220 miles is economically infeasible. The enormous cost of aqueduct facilities to meet the peaking requirements of the ultimate consumer is prohibitive. At this point it becomes necessary to compromise between the uniform annual rate of delivery, equivalent to 100 percent, and the assumed 188 percent daily peaking or 156 percent monthly peaking requirements in the Las Vegas Metropolitan subarea.



(FIG. III-1)

WATER USE CHARACTERISTICS OF LAS VEGAS VALLEY WATER DISTRICT ON A MONTHLY BASIS

The aqueduct facilities presented in this section have been designed to deliver water into the Las Vegas Metropolitan subarea at a maximum rate of 135 percent of the projected average daily use in year 2020. This compromise has been achieved by including terminal reservoirs located near the end of the aqueduct facilities. These reservoirs would be capable of releasing water at a rate of 135 percent of the projected average daily water use in year 2020. Reservoir capacity would vary from 11,000 to 14,000 acre feet. The advantage of these large reservoirs near the delivery point is that the aqueduct facilities upstream of the reservoirs could be sized to deliver water at 120 percent of average flow. Only those facilities downstream from the reservoirs have been designed to convey the 135 percent peaking deliveries. The proposed terminal storage would be at an elevation from which deliveries to Las Vegas Valley could be made by gravity. These reservoirs would serve an important role of helping to alleviate the shortage of emergency storage facilities in Las Vegas Valley. Although the matter of peaking characteristics warrants additional study should it be decided to further investigate interbasin transfers of water, the peak delivery of 135 percent of annual average compares favorably with the contracted agreements for the delivery of water from both the Feather River Project in California and from the Metropolitan Water District of Southern California transmission mains. Municipal and industrial water deliveries from both sources is contractually limited to 132 percent of the annual average use.

The effect of designing importation facilities for maximum delivery of 135 percent of average is that water requirements in excess of 135 percent of average which occur during the later years of the project must be supplied from local wells, local storage, or other sources.

3.01(c) Selection of Alignment

Aqueduct alignments, shown on Plate 1, have been determined by a study of the topography which lies between the source of supply and Las Vegas Valley. This topographic study has been made using USGS quadrangle sheets having a horizontal scale of 1:250,000 (approximately 1" = 4 miles) and a contour interval of 200 feet.

Field investigations of the alignments have not been conducted. A number of alignments between each source and Las Vegas Valley have been investigated and final paper alignments have been determined to meet the following requirements:

1. The wells and collection system have been located at an elevation of 100 to 200 feet above the trough of the source valley or playa, and between the playa and the mountains which furnish the major annual recharge. In this location the wells would intercept the most annual recharge and yield water of better quality than that found in the playa areas.

2. A second point on the alignment has been determined by the natural reservoir sites in Las Vegas Valley which are not in abundant supply. These reservoir sites also fix the elevation at which imported water must be delivered.

3. An attempt has been made to select alignments which would reduce the size and number of pumping stations.

4. Tunnels have been avoided wherever possible.

5. Since open channels generally are less costly than pipelines, alignments over terrain conducive to open channel construction have been selected whenever possible.

6. Alignments have been selected which would result in the internal pipeline pressures being held within tolerable limits.

7. Finally, an attempt has been made to incorporate all the above criteria while retaining a reasonably direct route from source to destination.

If the selected alignment is near an existing man-made facility such as a highway or power transmission line, the aqueduct alignment has been adjusted to parallel the existing facility, if possible.

3.01(d) Wells

The typical well and equipment assumed for use in this project would have a capacity of 5 cfs, a casing diameter of 20 inches and an average depth of 500 feet. The maximum pumping lift assumed to occur in year 2020 is 350 feet which would require a 300 horsepower motor at efficiencies of 75 to 80 percent. In order to reduce subsidence in the area of the collection channel, the wells have been located at least 1,000 feet from the channel. Water would be delivered to the collection channel by a 14-inch pipeline from each well. The wells have been spaced at one-half mile intervals along the collection channel. In the case of Amargosa Desert, and Pahrump and Railroad Valleys, wells have been located on one side of the collection channel only. In Pahranagat Valley, because of the shorter length of the collection channel, it has been necessary to locate wells on both sides of the collection channel at a distance of 2500 feet from the channel.

The total required well capacity has been taken as 125 percent of annual average aqueduct deliveries. This is 5 percent above the capacity of aqueduct facilities to allow for unavoidable system losses. The total cost for wells included in the cost summary includes a 30 percent allowance for well failure and replacement over the life of the project. Accordingly, the total number of wells required is 94 and 59 for the high and low growth rates respectively. The cost of constructing and equipping a well, including contingencies, has been estimated as $50,000 to $55,000 depending upon the location.

3.01(e) Collection Systems

The term collection system as used herein refers to those facilities required to transport the water from the well sites to the pumping station forebay and the aqueduct proper. The collection system would consist of two major segments; the pipeline from the individual wells to the collection channel, and the collection channel itself. As mentioned previously, the pipeline from the wells to the collection channel would be 14 inches in diameter and would vary from 1,000 to 2,500 feet in length.

The collection channel has been designed on the basis that it would be trapezoidal in shape, concrete lined, and vary in capacity from a minimum of 75 cfs to a maximum equal to the aqueduct design capacity. The bottom width of the open channel would vary from 4 to 10 feet while the depth of flow would vary from 2.5 to 5 feet. A minimum freeboard of one foot has been maintained for the concrete lining and an additional one foot for embankments. Collection channels have been paralleled by an asphalt service road 10 feet in width. Slope of the collection channel has been selected to limit the water velocities to 4 feet per second. Cost of the collection channel has been estimated to vary from $49 per linear foot for the 75 cfs channel to $103 per linear foot for the 350 cfs channel, including contingencies, but not engineering and other non-construction costs.

3.01(f) Open Channels

Open channels have been designed on the basis that they are concrete lined, trapezoidal in cross section, and designed to carry flows of 350 and 216 cfs. A Manning's "n" of 0.012 has been used in conjunction with 2 to 1 side slopes to determine the remaining geometric proportions of the cross section. Maximum velocity has been limited to 4 fps. Maximum depth of flow would be 5 feet and maximum channel bottom width would be 10 feet. A freeboard allowance of 1 foot has been used for the 4-inch reinforced concrete lining at design flows and the embankment has been designed an additional 1.5 feet above the concrete lining. A maintenance road 10 feet in width has been provided along one side of the channel. An average right-of-way requirement of 150 feet has been assumed and costs associated therewith have been included in the cost estimate. Estimated construction cost, including contingencies, of the open channels is $103 and $81 per linear foot for the 350 and 216 cfs channels respectively, which correspond to the maximum deliveries for the high and low growth rates.

3.01(g) Pipelines

Cost estimates of pipelines have been made on the basis of an average internal pressure of 600 feet and an average external cover of 5 feet. Hydraulic calculations have been based on a Manning's "n" of 0.011 and velocity has been limited to a maximum of 15 fps. Reservoirs have been located as near as practicable to pumping stations, power stations and energy dissipators in order to reduce the length of pipeline subject to dynamic hydraulic pressures which emanate from these sources.

A maintenance road 10 feet in width has been provided along the entire alignment. An average right-of-way strip 100 feet wide has been assumed and costs associated therewith have been included in the cost estimates. As an example, the cost of constructing an 84-inch pipeline in the Amargosa Desert, including contingencies, is estimated at $180 per linear foot.

3.01(h) Tunnels

For the purpose of the cost estimate, all tunnels have been assumed excavated to a diameter of 11 feet and have a finished inside diameter of 8 feet. Proposed tunnels would have very low internal pressures and would not be subject to hydraulic surge pressures. Lengths of the individual tunnels would vary from 1 to 8.5 miles. Geologic investigations along tunnel alignments have not been conducted. The assumed structural elements of the tunnels would consist of circular 8WF 28 supports 4 feet on centers and an 18-inch concrete lining. The estimated cost of the tunnels is $521 per linear foot, including contingencies.

3.01(i) Pumping Stations

Pumping stations would be required to lift the water over the mountain ranges which must be crossed. The cost of these pumping stations has been estimated based on a reserve capacity of 10 percent and a pump efficiency of 90 percent. The horsepower rating of the pumping stations would range from 2,100 to 65,000 horsepower. The average pumping station cost has been estimated at $323 per horsepower, including contingencies. The cost of the pumping station forebay and afterbay, discharge line and power transmission have been included in other items.

3.01(j) Power Stations

The availability of low cost power in southern Nevada results in the possible hydropower plants being economically infeasible in the Las Vegas area. The estimated cost of generating power from this project ranges between 10 mills/ and 20 mills/kwh. In comparison with this, the Nevada Power Company charges the residential user about 7 mills/kwh after a monthly service charge; therefore the estimated 10 mills/ to 20 mills/kwh power generated as part of the interbasin movement of water would be unmarketable. Although a peak power pumping system could prove economically feasible it has not been investigated because it would entail rather substantial capital investments while not being essential for the delivery of water.

The Railroad-Las Vegas aqueduct is the only system on which a power plant has been considered feasible. The two factors which combine to make a power development feasible for this aqueduct are the 150-mile distance from the Las Vegas area from which power for the pumping station would have to be transmitted, and the availability of a relatively high hydraulic drop of 1440 feet. The power generated would be consumed by the well pumps and booster pumping stations of the aqueduct system.

In light of the above discussion it has been assumed that power would be purchased in the Las Vegas area and transmitted to the aqueduct pumping stations and well pumps, except for the Railroad-Las Vegas aqueduct. Since the quantity of power required is substantial and the distance the power must be transmitted ranges from 75 to 200 miles, it has been assumed that the power transmission lines would be constructed as part of the aqueduct facilities and costs therefor are included in the cost estimate. After construction, it has been assumed that the power company having jurisdiction in the area in which the power is required would operate and maintain the facilities. These assumptions have been made so as not to impose unusual financial burdens on the small power companies responsible for remote rural areas and are not meant to preclude alternative solutions.

The cost of high voltage power transmission lines has been estimated at $40,000 per mile for lines of 40,000 kilowatt capacity and $16,000 per mile for lines of 12,000 kilowatt capacity. These figures include an allowance for the rugged terrain through which they would have to be constructed. Cost for substations also has been included in the cost of power transmission.

The price of purchased power has been assumed at 10 mills/kwh in order to calculate the annual cost of operation of the aqueduct. This cost presupposes that the transmission facilities and substations would have been constructed as part of the aqueduct project.

3.01(k) Reservoirs

There are three general types of reservoirs proposed; lined, lined and covered and large unlined reservoirs formed behind earthfill dams. The line and the lined and covered categories are termed regulating reservoirs. The storage capacity of the regulating reservoirs is conveniently expressed as the number of hours of the aqueduct design flow it would take to fill the reservoir. The following table shows the corresponding reservoir capacity in acre feet for design flows of 350 and 216 cfs.

Rated Storage Capacity (hr)	Design Flow	
	Q = 350 cfs Storage (Ac. Ft.)	Q = 216 cfs Storage (Ac. Ft.)
12	350	216
24	700	432

3.01(k)1 Lined Reservoirs. All regulating reservoirs, forebays and afterbays having storage capacity rating of 12 or 24 hours have been assumed to be lined. Lining is required to reduce leakage, to prevent the water from picking up sand and silt which would have an erosive effect on aqueduct facilities, and to prevent instability of earthen embankments due to the rapid rise and fall of the water surface expected in regulating reservoirs of this type. The reservoirs have been assumed to be lined with asphalt cement and a rubber membrane at a unit cost of $0.50 per square foot. The average cost of a 24-hour reservoir is $3,160,000 and $1,945,000 for the high and low rates of growth respectively.

3.01(k)2 Lined and Covered Reservoirs. Each of the aqueducts would have a covered terminal reservoir just downstream of the treatment plant at an elevation of 2500 feet which would be used for the storage of treated water. These covered reservoirs would have a 12-hour storage capacity. The respective average cost of these reservoirs for the high and low growth rates has been estimated at $6,850,000 and $3,930,000.

3.01(k)3 Dam and Reservoir. Two natural dam sites appear to exist in the Las Vegas Valley conveniently close to the aqueduct alignments and at an elevation which would not require additional pumping. It is emphasized that no geologic testing has been conducted at the proposed sites. The dam sites have been selected from a topographic map and visually inspected in the field.

The site which will provide storage for the aqueducts from the Railroad, Pahranagat and Amargosa aqueducts is located approximately 6 miles north of Nellis Air Force Base. The height of dam required to provide 14,000 acre feet of storage would be 220 feet and the length of the dam at its crest would be 2,700 feet. The water surface elevation when the reservoir is full would be 3,060 feet above sea level. Outflow could be made from a full reservoir at the maximum rate of 135 percent of the average annual design flow, equivalent to 400 cfs, for 17.5 days with no inflow to the reservoir.

Assuming side slopes of 3:1, the estimated volume of earth in the dam would be 11,550,000 cubic yards. The required spillway capacity has been estimated at 7,000 cfs. The cost of the dam is estimated at $16,800,000, including contingencies.

The reservoir site selected for the Pahrump system is located in the Red Rock Canyon area. A dam height of 400 feet would be required to creat a reservoir having a capacity of 11,000 acre feet. The high dam is required by the nature of the canyon which is narrow with very steep rock walls. The length of the dam at its crest would be only 1,200 feet and would be only 700 feet at mid-height.

An earthfill dam constructed on the site with 3:1 side slopes, would require approximately 6,450,000 cubic yards of fill material. The spillway capacity has been estimated at 3,000 cfs. The cost of the dam is estimated at $11,700,000, including contingencies.

Visual inspection of the site in a narrow canyon with steep walls suggests the use of a concrete arch dam rather than an earth fill dam. If the canyon walls are as structurally sound as they appear, the use of a concrete arch dam could result in lower dam costs.

3.01(l) Treatment Facilities

Because of the many open channels and uncovered reservoirs and the length of time that aqueduct water would be in storage, contamination could occur to an otherwise potable well water supply. Therefore, treatment plants have been assumed to be needed and the cost estimates have been based on filtering and chlorinating all imported water before it enters the Las Vegas distribution systems. Sedimentation would be accomplished in the large reservoirs located about two miles upstream of the treatment plants.

In order to solve the fluoride problem, water from Amargosa Desert would be blended with water from the SNWP project on an estimated 1:1 ratio to lower the fluoride concentration to that recommended by the U.S. Public Health Service, 1962 Drinking Water Standards (see Table II-4). A pumping station capable of lifting SNWP water 350 feet to the 2500-foot elevation of the treatment plants plus 10 miles of pipeline have been assumed as the facilities required for blending. The cost, including contingencies, of these blending facilities has been estimated at $17,500,000 and $13,900,000 for the high and low growth rates.

Except for the fluoride problem, the quality of water from the areas of export is generally superior to that of the Colorado mainstem, particularly in regard to total dissolved solids. Also, the Colorado River mainstem is predicted (16) to deteriorate in quality in the future. The cost of blending the better quality imported water with Colorado River water would be prohibitive because of the distances and differences in elevation involved and it is not recommended except in the Amargosa Plan.

The treatment plants have been designed to handle maximum flows of 135 percent of the annual average, since they are located below the reservoirs. The resulting plant rated capacities are 280 mgd and 175 mgd. The cost of the treatment plants, including contingencies, has been estimated at $25,000,000 and $15,000,000 for the high and low growth rates respectively.

3.01(m) Energy Dissipating Stations

As described in subsection 3.01(j) the availability of low cost power in the study area results in the possible hydropower plants being economically infeasible and therefore, it would be necessary to incorporate energy dissipating stations in each aqueduct. For the purposes of this report it has been assumed that energy dissipators would consist of many small size valves instead of large size needle valves or Howell-Bunger type valves. The estimated construction cost of these energy dissipators varies from a high of $3,000,000 to a low of $1,200,000.

3.01(n) Terminal Points

The terminal points of the aqueducts have been assumed 6 miles distant from downtown Las Vegas. This has been done because by the year 1993 or 2008, when aqueduct construction is scheduled to be completed for the high and low growth rates respectively, the urban development of Las Vegas Metropolitan subarea is expected to reach a radius 6 miles from the center of Las Vegas. The elevations of aqueduct termini are 2500 or 2000 feet above sea level. However, the hydraulic grade line at the terminal points would be slightly below elevation 2500 for all aqueducts except the Virgin River so that water could be supplied to the Las Vegas Metropolitan subarea by gravity.

3.02 COST ESTIMATES

3.02(a) Construction Costs

All cost estimates which have been prepared for this report assume material and labor costs at prevailing 1970 prices. The Engineering News Record cost index for 1970 has been assumed at 1400. Where it has been necessary to incorporate the costs estimated by others into this report they have been adjusted to an ENR index of 1400.

Due to the remoteness of many of the aqueduct facilities a premium has been included in the estimated construction costs. This premium is the increase in the cost of constructing identical facilities near an urban area in order to cover the cost of providing living facilities for the workers in areas along aqueduct alignments where there are inadequate housing facilities and in order to defray the cost of transporting men and materials to the work site. The amount of the premium has been estimated to be 15 percent for Railroad Valley, 7.5 percent for Amargosa Desert and Pahranagat Valley and 5 percent for Pahrump Valley. This premium has been included in the construction costs given in this report.

The unit cost of water in the intrastate water transfer plans, with the exception of the Railroad Valley plan would increase as the size and capacity of the aqueduct increase. This is contrary to the normally encountered case where unit prices decrease with larger volumes of a commodity sold or delivered.

This anomaly occurs because the total quantity of water available for export is constant. If the high growth rate is realized, then larger aqueduct facilities must be constructed. Consequently the associated higher cost must be prorated over the same total quantity of water as the smaller and less costly facilities required for the lower growth rates and higher unit costs are inevitable.

Railroad Valley is the one exception because the total amount of water imported for the high and low growth rates is not constant. The Railroad Valley project life is not limited by the available supply as in the other subareas, but by the assumed maximum life span of 50 years (see section 3.02(b).

3.02(b) Amortization Period - Project Life

The amortization period is synonymous with the project life. With the termination of aqueduct deliveries due to exhaustion of available water supply, the ability of the aqueduct to develop revenue will cease and all costs for these facilities must have been repaid with interest at this point in time.

The life of the four plans developed in this report for the intrastate transfer of water, with one exception, has been determined by the supply of water available in the respective areas from which the supply would be obtained. The bulk of all water considered for importation to the Las Vegas Metropolitan subarea is ground water. The mining of ground water results in the lowering of the water table. For this study, it has been assumed that the equivalent amount of water in the upper 100 feet of saturated material in each of the respective supply areas would be available for export. The span of time that it would take to export this quantity of water is considered the useful life of the facilities for the intrastate transfer of water.

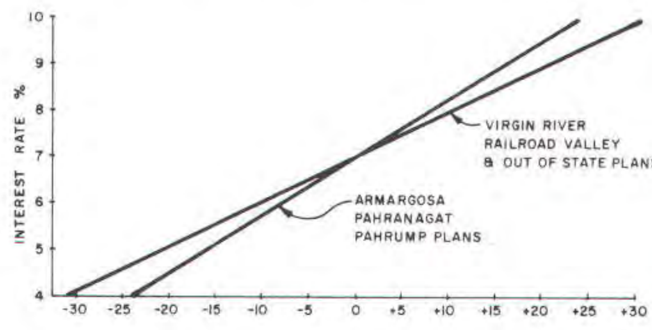
The method used to determine project life is presented graphically on Figures III-2 through III-5. The portion of the curve representing Las Vegas water demands rises upward to the right until the capacity of the aqueduct facilities is reached. Then the aqueduct capacity is represented by a horizontal line on the graph. The area under the curve represents the volume of water imported by Las Vegas Metropolitan subarea. The area under the curve increases as time progresses. When the area corresponds to the calculated volume of ground water in the upper 100 feet of the ground-water basin, plus that portion of annual recharge which is available for exportation, deliveries from the supply area have been considered to be terminated. In Pahrump the total annual recharge has been considered to be reserved for local domestic use and the quantity of water exported has been restricted to ground-water in storage. The total amount of water imported from Amargosa Desert would vary by 60,000 acre feet for the high and low growth rates. This difference is the recharge of 20,000 acre feet per year for the three years difference in project life (assuming that 4,000 acre feet per year would be lost to the evaporation cycle) which has been assumed available for importation. In the case of Railroad Valley the volume exported has been considered to be limited by the maximum life of 50 years assumed for the intrastate aqueducts. The same reasoning applies to Pahranagat Valley as for Amargosa Desert.

The year in which importation of water from an area must be stopped, of course, is the end of the useful life of the project. Based on projected water demands for Las Vegas Metropolitan subarea, it is known in which years deficiencies first occur; namely in the case of high growth rate 1993, and in the case of low growth rate 2008. By subtraction, it is possible to determine the life span of each of the importation plans. As can be seen from Figures III-2 to III-5, life spans of intrastate water transfer plans would vary from 26 to 50 years. The maximum life span for intrastate water transfer facilities has been arbitrarily limited to 50 years. This has been done because it is felt federal participation in these projects cannot be assured and that private investors would be reluctant to invest funds for periods over 50 years.

3.02(c) Interest

An interest rate of 7 percent has been assumed as reflecting a reasonable rate at which financing for the projects could be obtained. All project costs have been amortized over the entire project life discussed in subsection 3.02(b) at this 7 percent rate beginning in the year aqueduct construction is completed. Interest during construction has also been computed using the 7 percent interest rate and reinvestment of unused funds. Time of construction has been assumed as 6 years for the aqueduct from Railroad Valley and 4 years for the aqueduct from Amargosa Desert, Pahranagat Valley, and Pahrump Valley.

The effect on the price of project water for interest rates other than 7 percent can be estimated using the figure below. For example, the effect of using an interest rate of 5-1/8 percent (presently used by Federal agencies in the formulation and evaluation of plans for water and related land resources projects) is to decrease the price of project water approximately 20 percent in the case of Railroad Valley, Virgin River Valley and the interstate plans, and approximately 15.5 percent in the case of Amargosa Desert, Pahranagat Valley and Pahrump Valley.



EFFECT ON THE PRICE OF PROJECT WATER DELIVERED TO LAS VEGAS (%)

3.02(d) Contingencies

To the estimated cost of the aqueduct facilities a 20 percent contingency factor has been applied. The resultant cost after adding the contingency is for the purpose of this report defined as the construction cost.

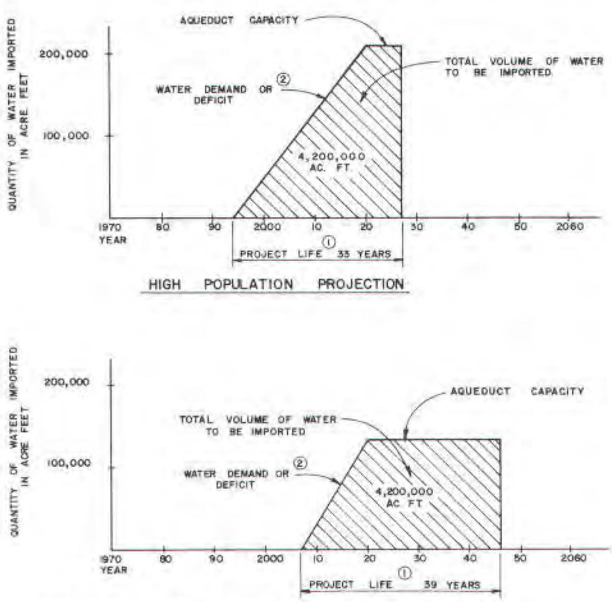
3.02(e) Engineering, Administration, Legal and Bond Marketing

The engineering, administration, inspection, legal and bond marketing expenses have been assumed at 15 percent of the construction cost.

3.02(f) Operation and Maintenance

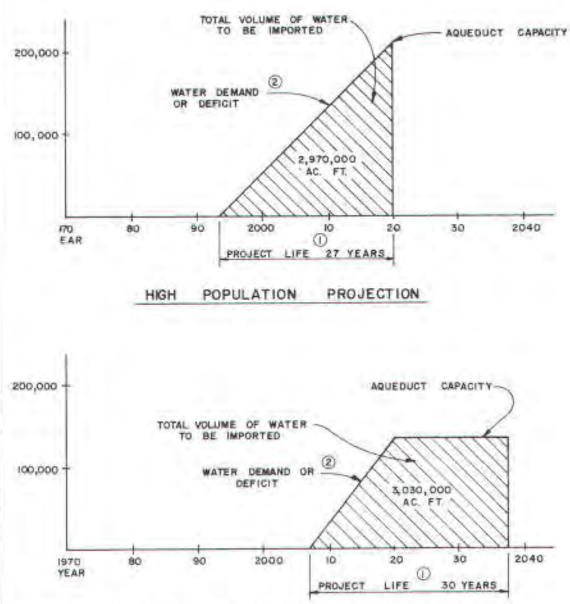
Operation and maintenance costs have been estimated as the sum of three components; (1) power costs, (2) treatment plant operation costs, and (3) operation and maintenance costs associated with the aqueducts. Annual power costs have been estimated by using a unit power cost of 1 cent per kilowatt hour and assuming an efficiency of 85 and 70 percent for pumping stations and wells, respectively. The costs of operating the treatment plants have been estimated using information on the operation of the La Verne and Diemer filtration plants of the Metropolitan Water District of Southern California.

SUPPLEMENTAL WATER SOURCES
WITHIN NEVADA



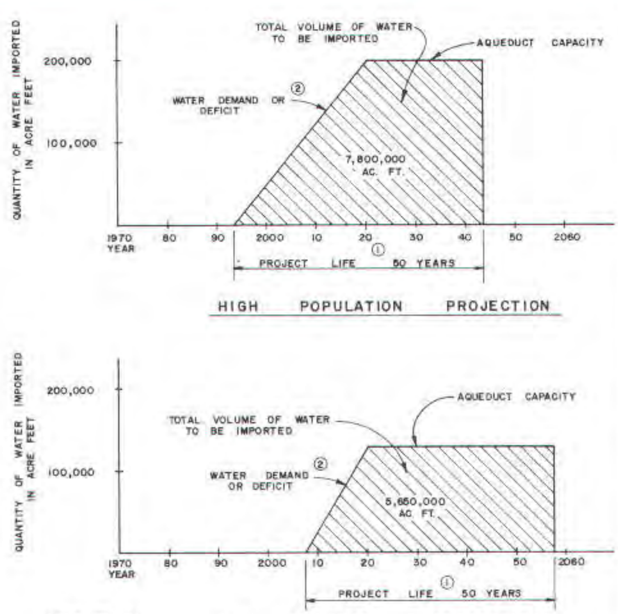
(FIG. III-2) LOW POPULATION PROJECTION

PROJECT LIFE OF AQUEDUCT BETWEEN PAHRUMP & LAS VEGAS



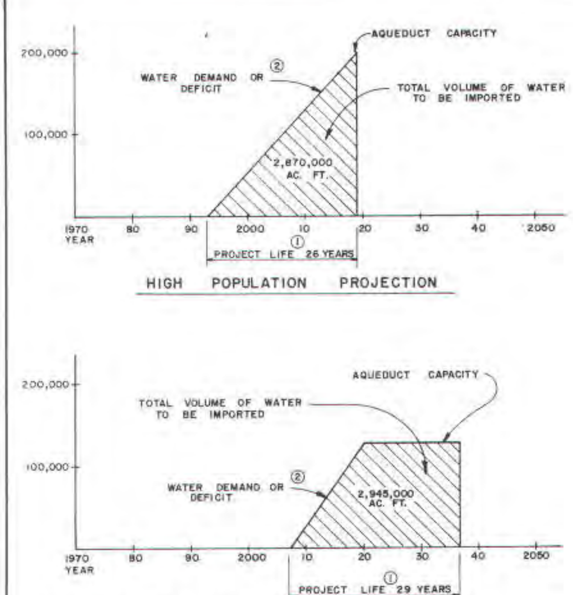
(FIG. III-3) LOW POPULATION PROJECTION

PROJECT LIFE OF AQUEDUCT BETWEEN AMARGOSA & LAS VEGAS



(FIG. III-4) LOW POPULATION PROJECTION

PROJECT LIFE OF AQUEDUCT BETWEEN RAILROAD & LAS VEGAS



(FIG. III-5) LOW POPULATION PROJECTION

PROJECT LIFE OF AQUEDUCT BETWEEN PAHRANAGAT & LAS VEGAS

① PROJECT LIFE - TIME REQUIRED TO LOWER WATER TABLE THE EQUIVALENT OF 100FEET OR 50 YEARS, WHICHEVER IS SHORTER.

② ASSUMING CURRENT PATTERNS OF PER CAPITA WATER USE CONTINUE.

Operation and maintenance of the aqueduct facilities has been estimated by updating the estimated operation and maintenance costs in the Bureau of Reclamation Report on the Southern Nevada Water Project (17) .

3.03 PAHRUMP VALLEY AS A SOURCE OF SUPPLY

3.03(a) Amount of Water Available

The estimated total amount of ground water stored in Pahrump Valley is 22,500,000 acre feet of which 6,000,000 acre feet occurs in the top 100 feet of saturated fill. Perennial yield has been estimated at 12,000 acre feet per year. For the purpose of estimating the project life of the aqueduct it has been assumed that the configuration of the collection system would allow extraction and exportation of 70 percent (4,200,000 acre feet) of the equivalent amount of water in the upper 100 feet of saturated material. The perennial yield of 12,000 acre feet per year has been assumed to be reserved entirely for existing development and domestic use in Pahrump and has not been considered available for export.

3.03(b) Life of Project

When the assumed water requirements of the Las Vegas Metropolitan subarea and aqueduct capacities have been considered, the 4,200,000 acre feet of water assumed available for export would be exhausted in 33 or 39 years after exportation begins, as shown graphically in Figure III-2.

3.03(c) Description of Aqueduct Facilities

The aqueduct from Pahrump would have a total length of 74.5 miles, of which 39 miles would be trapezoidal open channel, 8.5 miles would be tunnel, 26.5 miles would be pipeline, and 0.5 mile would be reservoir. The Spring Mountains are located between Pahrump and Las Vegas and constitute a formidable natural barrier which would have to be crossed. Alignments circumventing the Spring Mountains to the north and to the south have been considered, but would result in higher construction costs. The aqueduct profile is shown in Figure III-6 and the aqueduct alignment is shown in Plate 1.

The aqueduct would begin at a point which is approximately 12 miles northwest of the town of Pahrump and at an elevation of 2900 feet. The first 39 miles of the aqueduct would constitute the collection system. It generally would follow the 2900 foot contour. This collection channel would deliver water to the pumping station forebay with a 24-hour storage capacity. The water would then be lifted 750 feet by pumping station No. 1 through five miles of pipeline to the forebay of pumping station No. 2. Pumping station No. 2 would then lift the water an additional 750 feet through 4.5 miles of pipeline to the pumping station afterbay which would serve as the tunnel inlet facility. Pumping stations No. 1 and No. 2 have been assumed identical and would have a power rating of 36,300 horsepower or 22,300 horsepower each. The pumping station afterbay and tunnel inlet would have a capacity of 12 hours design flow and would be located at an elevation of 4300 feet. The water would then flow in a 8.5 mile tunnel through the Spring Mountains. From the tunnel, water would be delivered to the large storage reservoir at mile 64.8 through 7.8 miles of pipeline. The proposed storage reservoir for the Pahrump aqueduct has been located in the Red Rock Canyon area of Las Vegas Valley, as described in subsection 3.01(k)3.

Water would leave the dam through the outlet works and travel approximately one mile through a pipeline to an energy dissipating station which would dissipate 800 feet of head when the reservoir is full. The water would be discharged immediately into a lined reservoir having a storage capacity of twelve hours. The water would then flow through 8.2 miles of pipeline to a second energy dissipating station where a second 800 feet of energy would be dissipated before the water flows into another lined reservoir of 12-hour storage capacity. The water would then enter the treatment plant where it would be filtered and chlorinated and then flow directly to the terminal storage reservoir which would be lined and covered and have a 12-hour storage capacity. This terminal storage reservoir would be at mile 74.5 and would mark the end of the aqueduct. Water would flow from this reservoir directly into a water distribution system in the Las Vegas Metropolitan subarea.

Total project right of way requirements have been estimated at 2,800 acres of which 660 acres are privately owned and the remainder is owned by units of local state and federal government. Right of way costs have been calculated at an average cost of $500/acre, and are included in construction costs.

3.03(d) Cost of System

The total estimated capital cost of the aqueduct facilities from Pahrump to Las Vegas Valley is $237,932,000 and $185,555,000 for the high and low growth rates respectively. These estimates include $17,280,000 for the purchase of farms and associated water rights in Pahrump Valley, as discussed in Subsection 3.03(e). A breakdown of the capital costs is given in Figure III-6.

The annual average operation and maintenance costs of the project have been estimated as follows:

ITEM	Q = 350 cfs	Q = 216 cfs
Annual Power Costs	$2,930,000	$2,491,000
Treatment Plant Operations	1,210,000	1,032,000
Operation, Maintenance and Replacement	950,000	720,000
Total Annual Cost of Operation and Maintenance	$5,090,000	$4,243,000

Although there are two pumping stations, each with a 750-foot lift, they would be only five miles apart which would result in some economization of the operation and maintenance costs.

The total annual cost of the system is the sum of the amortized capital cost and total annual cost of operation and maintenance. It has been estimated to be $23,740,000 and $18,143,000 for the high and low growth rates. Since average deliveries over the life of the project are 127,500 acre feet per year and 108,000 acre feet per year, the resulting unit cost of water would be $186 and $168 per acre foot for the high and low growth rates respectively. This information is summarized in Figure III-6.

3.03(e) Effects on Pahrump If System Implemented

3.03(e)1 Farming. The major impact of the project would be to end or seriously reduce agriculture in the Pahrump Valley. There are about 35 farms that would have to be bought or at least their water rights purchased which would mean their end as farms. These farms have presently about 11,000 acres under cultivation. Most valuable are 3,400 acres that have cotton allotments. The end of farming would also terminate the activities of a cotton gin and farm equipment dealer in the town of Pahrump.

3.03(e)2 Residential Development. The project would not disturb the non-agricultural growth of Pahrump. The annual ground-water recharge and storage is sufficient for both the project and Pahrump's non-agricultural growth through the year 2020. Domestic users could tolerate the increased depth to water caused by the project, but probably would incur additional expenses associated with deepening wells, lowering pumps, and lifting water a greater distance.

3.03(e)3 Total Economic Impact. Other than the cotton gin and the farm equipment firm, adverse impact upon existing business enterprises would be slight. At most sales to the owners and workers on the 35 farms and their families would be lost. Present retail activity is of a road side nature or involves sales to the local residents who work chiefly at the Nevada Test site or in Las Vegas. The project would in no way affect the number of these residents. There would be no need to buy private residential sites with domestic wells. All other land with water rights would be bought in which case the purchase of 18,000 acres would be involved.

The value of agricultural land in the Pahrump Valley is affected by its potential for real estate subdivision purposes. While the best cotton land is worth about $600 an acre, unimproved land ready for subdivision is worth about $1,000 an acre. An average value of $800 for all land with water rights would appear reasonable. With the addition of 20 percent to this figure for the actual costs involved in land and water right acquisition, total outlays to secure water rights could be as high as $17,280,000 for the 18,000 acres involved. Costs would however be presumably lower than this if only water rights were purchased or if the land without irrigation rights was subsequently resold for residential purposes.

3.03(e)4 Subsidence. One problem associated with a lowering of the ground water table is subsidence of the land surface. As water levels decline, the hydrostatic pressure in any individual underground stratum within the zone of saturation is reduced. The reduction in hydrostatic pressure causes an increase in the overburden load carried by the stratum, hence consolidation takes place. The pumpage from the four subareas in which it is proposed to develop ground water would result in lowering the water table approximately 100 feet and subsidence could occur in each of these subareas as it has occurred in Las Vegas Valley.

Subsidence in built up portions of Las Vegas Valley has exceeded 3 feet in some areas (18) and has resulted in no serious adverse effects to existing man made structures. This is possible because the settlement occurs more or less uniformly over large areas and it occurs very slowly. The subsidence anticipated in the source areas would be about double the subsidence experienced in Las Vegas Valley to date and should have no serious effect upon man made structures.

3.04 AMARGOSA DESERT AS A SOURCE OF SUPPLY

When considering Amargosa as a source of supply, consideration has been given to its proximity to the Nevada Test Site and the testing program that has been undertaken.

The aqueduct alignment passes within a few miles of the test site. The magnitude of ground accelerations due to future nuclear testing has been investigated. The Atomic Energy Commission predicts that maximum ground accelerations will be less than 0.043g. Since aqueduct facilities are normally designed for a minimum of 0.100g ground accelerations due to naturally occurring seismic activity, the dynamic effects of the atomic testing should have no affect on aqueduct facilities.

As mentioned in subsection 2.01(g) 2 there is substantial evidence to support the theory of interbasin transfer of ground water through the carbonate rocks underlying more recent alluvium and volcanic deposits. If it were decided to use the Amargosa Desert ground-water basin as a source of water to export to Las Vegas Metropolitan subarea, an investigation of the possible interbasin flow between the contaminated ground water at the test site and Amargosa would be warranted.

3.04(a) Amount of Water Available

The amount of ground water in storage in the Amargosa ground-water basin has been estimated to be 24,000,000 acre feet in the top 800 feet of valley fill, of which 2,700,000 acre feet occurs in the upper 100 feet of saturated valley fill. The portion of the annual recharge which is assumed available for export is 20,000 acre feet per year. For the purpose of estimating the useful life of the aqueduct it has been assumed that the configuration of the collection system would allow extraction of 90 percent or 2,400,000 acre feet of the equivalent amount of water in the upper 100 feet of saturated material.

3.04(b) Life of Project

The 2,400,000 acre feet from storage plus 20,000 acre feet per year of the annual recharge considered available for export would be exhausted in 27 or 30 years after exportation begins as shown graphically in Figure III-3.

3.04(c) Description of Aqueduct Facilities

The aqueduct from Armargosa Desert would have a total length of 131 miles of which 88 miles would be trapezoidal open channel and 43 miles would be pipeline. A profile of the proposed aqueduct is shown in Figure III-7. The aqueduct would begin at a point which is approximately 12 miles due west of Lathrop Wells at an elevation of 2,500 feet. The first 45 miles of the aqueduct would constitute the collection system. The collection channel would generally follow the 2,400 foot contour as shown on Plate I. The collection channel would deliver water to the pumping station forebay which would have a design capacity of 24 hours storage. A 65,000 horsepower or 40,000 horsepower pumping station would then lift the water 1,350 feet through 17.5 miles of pipeline to the pumping station afterbay at elevation 3,650 feet. The storage capacity of the pumping station afterbay would be rated at 12 hours. The water would then flow through 12 miles of open channel to a regulating reservoir having a storage capacity of 12 hours. The water would then enter a 5-mile pipeline and pass through an energy dissipating station which would dissipate 400 feet of head and enter a second regulating reservoir which would have a 12-hour storage capacity. The water would then be conveyed by a 13.5 mile open channel to an inverted siphon having a length of four miles which would be required to cross Corn Creek. It would then continue its journey through a 17-mile open channel to a regulating reservoir having a capacity of 24 hours storage. From this point on, the terrain becomes more rugged and an 11-mile pipeline would be required to deliver the water to the large reservoir near the aqueduct terminus. The location of this dam and reservoir is approximately 6 miles north of Nellis Air Force Base, as described in Subsection 3.01(k)3.

The water would then flow via a 2-mile pipeline to an energy dissipating station which will dissipate 500 feet of energy and then would enter a regulating reservoir having a storage capacity of 12 hours. The water then would pass through the treatment plant where it would be filtered, blended with an equal quantity of water from the Southern Nevada Water Project or Las Vegas ground-water basin, and then flow into the terminal storage reservoir which would be lined and covered and would have a storage capacity of 12 hours. The water blending would be required to reduce the fluoride concentration in the water from Amargosa Desert as described in Subsection 3.01(l).

The water would then move from the covered reservoir through 6 miles of pipeline to the aqueduct terminus at Mile 131, located at elevation 2000 feet. The aqueduct terminus would be approximately 6 miles from downtown Las Vegas. At this point it is assumed that the water would enter a distribution system of the Las Vegas Metropolitan subarea.

Total project right-of-way requirements have been estimated at 4,300 acres of which 300 acres are privately owned, the remaining 4,000 acres being owned by units of local, state, and federal governments. Right of way costs have been estimated at an average cost of $500/acre and are included in construction costs.

3.04(d) Cost of System

The capital cost of the aqueduct facilities from Amargosa Desert to the Las Vegas Metropolitan subarea has been estimated at $294,923,000 and $226,579,000 for the high and low rates respectively. These estimates include $10,200,000 for the purchase of farms and associated water rights in Amargosa Desert, as discussed in subsection 3.04(e). A breakdown of the project capital costs is given in Figure III-7.

The annual average operation and maintenance costs of the project have been estimated as follows:

ITEM	Q = 350 cfs	Q = 216 cfs
Annual Power Costs	$2,800,000	$2,576,000
Treatment Plant Operation	1,050,000	965,000
Operation, Maintenance and Replacement	1,230,000	927,000
Total Annual Cost of Operation and Maintenance	$5,080,000	$4,468,000

The total annual cost of the system is the sum of the amortized capital cost computed at 7 percent rate of interest and the total annual cost of operating and maintaining the aqueduct facilities and has been estimated at $29,680,000 and $22,738,000 for the high and low growth rates.

Annual aqueduct deliveries from Amargosa Desert have been calculated to average 110,000 and 101,000 acre feet over the life of the project and result in an average unit water cost of $270 and $225 per acre foot for the high and low growth rates respectively. This information is also summarized on Figure III-7.

3.04(e) Effect on Amargosa Desert If System Implemented

3.04(e)1 Farming. The project would end or seriously reduce farming in the Amargosa Desert. Present irrigation development is limited to about twenty-five full time farms.

For the purposes of this study, acquisition of 17,000 acres of land with water rights has been considered necessary. This land involves areas brought only recently into cultivation with considerable improvements as well as land not now cultivated. Using an average value of $500 an acre plus an allowance of 20 percent for acquisition costs, reasonable payment for the water rights of the area might involve as much as $10,200,000.

3.04(e)2 Residential Development. The Amargosa Desert is very sparsely settled. The largest town, Beatty, is at the extreme north edge with 1,200 people. Other communities, each with less than 100 people are Lathrop Wells and Ash Meadows. Possibly 300 people live in the unincorporated areas. The principal employment of the inhabitants of the area is provided by the Nevada Test Site. There is a minimal amount of employment in agriculture and roadside activity.

3.04(e)3 Total Economic Impact. The economic impact of the project would be minimal in that it would only involve twenty-five farms at most. It would certainly not affect the communities in the area which are not even developed trade centers used by the farm group. There would be adequate water available for the communities in whatever conceivable growth they may experience in the future. Such growth would probably be based on tourism generated by the areas within proximity to Death Valley rather than based on farming.

3.04(e)4 Non-Economic Considerations. The area contains a rare fish that lives in the deep water holes and seeps of the area. This fish, the pupfish, is of particular concern to conservationists, since this area of the United States is the only place in the world where this fish is found. The pupfish is threatened with extinction by the lowering of the water table. Extensive scientific and conservationist literature has been published in regard to this fish and its preservation. The pupfish is believed to be one of the oldest living forms of life. The fact that it has survived enormous climatic changes in the area over millions of years and that it presently lives in water temperatures ranging from near freezing to over 100 degrees has caused one writer to contend that it may well "hold the secret of life for man."

In any case, its preservation was the main topic of discussion at a conference held at Furnace Creek, California in November 1969 and it caused the U.S. Department of the Interior to publish a pamphlet entitled "Let's Save the Desert Pupfish." The Department lists five things it will do to preserve the pupfish. Among the actions it plans is to "have the State of Nevada limit additions to irrigation and to restrict pumping which would result in the lowering of underground water supplies." The proposed water exportation project would result in a further lowering of the water table and possibly the destruction of the pupfish habitat as it presently exists. The Department of Interior also proposed to initiate a program to locate "other water areas to which portions of an endangered species can be moved to help assure survival." From the note of immediacy in current literature it is possible that the pupfish will be destroyed by the falling water table or satisfactorily transferred to safety elsewhere prior to the inauguration of the proposed water exportation project.

3.04(e)5 Subsidence. For a discussion of subsidence refer to Subsection 3.03(e)4.

3.05 RAILROAD VALLEY AS A SOURCE OF SUPPLY

3.05(a) Amount of Water Available

The estimated total amount of ground water stored in Railroad Valley in the top 100 feet of saturated valley fill is 7 million acre feet. The perennial yield has been estimated at 52,000 acre feet per year. For the purpose of estimating the project life of the aqueduct, it has been assumed that the configuration of the collection channel would allow extraction and exportation of 70 percent of the equivalent hydroelectric plant located in Pahranagat Valley. For this reason, the cost of power for the Railroad Valley plan has been estimated at 5 mills/kwh rather than the 10 mills/kwh used elsewhere.

The total annual cost of the system is the sum of the amortized capital cost and the total cost of operation and maintenance and has been estimated at $39,339,000 and $30,336,000 for the high and low growth rates respectively. Since the average deliveries over the life of project have been calculated at 156,000 and 113,000 acre feet per year, the resulting unit cost of water would be $252 or $268 per acre foot for the high and low growth rates respectively. This information has been summarized on Figure III-8.

3.05(e) Effect on Railroad Valley If System Implemented

3.05(e)1 Farming. The major activity in Railroad Valley is farming although there is some oil production. The project would lower the water table in the valley and might require the purchase of 3,500 acres of land which now have water rights. Not all of this land is presently cultivated. A conservatively high average value of $400 an acre plus the usual 20 percent addition involved in connection with acquisition costs would involve an outlay of $1,680,000 for reparations.

3.05(e)2 Total Economic Impact. Of the four proposed water supply projects, the Railroad Valley project would involve the least outlay for water rights and also the least unfavorable economic and non-economic impact. Unfortunately, as the most distant project from the Las Vegas Metropolitan area, it remains the most expensive despite these advantages.

3.05(e)3 Subsidence. For a discussion of subsidence see subsection 3.03(e)4.

3.06 PAHRANAGAT AS A SOURCE OF SUPPLY

3.06(a) Amount of Water Available

The estimated total amount of ground water stored in the top 100 feet of the saturated valley fill is 2,200,000 acre feet. The total perennial yield has been estimated at 25,000 acre feet per year. For the purpose of estimating the project life of the aqueduct, it has been assumed that the configuration of the collection system would allow extraction of 100 percent of the equivalent amount of water in the upper 100 feet of the saturated material and that the perennial yield of 25,000 acre feet per year would be available for export.

3.06(b) Life of Project

When the assumed water requirements of the Las Vegas Metropolitan subarea and the aqueduct capacities have been considered, the 2.2 million acre feet of ground water plus the total perennial yield 25,000 acre feet per year would be exhausted in 26 or 29 years after exportation begins, as shown graphically in Figure III-5.

3.06(c) Description of Aqueduct Facilities

The aqueduct from Pahranagat would have a total length of 109.6 miles which may be subdivided into 25.6 miles of trapezoidal open channel, 82 miles of pipeline, a 1-mile tunnel and 1 mile of reservoirs. There are no mountain ranges between the Pahranagat Valley and the Las Vegas Valley which must be crossed. In fact, water from Pahranagat would flow by gravity to Las Vegas Valley. One small booster pumping station has been incorporated in the aqueduct plan to lift water from the collection channel 200 feet in order to reduce the required diameter of the 74-mile pipeline.

The aqueduct would begin at a point near Hiko in the Pahranagat Valley and at an elevation of 3,900 feet. The first 25.6 miles of the aqueduct would consist of the collection system. Although the resultant alignment of the collection channel would follow the Pahranagat Valley it would be necessary to route the open channel in a manner to conform more or less to the contour lines and then provide two baffled spillways to drop the water a total of 260 feet. This would be necessary in order to limit the velocity in the channel to 4 feet per second. The water from the first 18 miles of the collection channel would flow into a reservoir having a storage capacity of 24 hours from which it would enter a 74-mile pipeline. The water in the second 7.6 miles of the collection system would be collected at ground level and then pumped into the 74-mile pipeline at a hydraulic gradient which would be 200 feet above the ground surface. After traveling through the 74-mile pipeline the water would pass through a 1-mile tunnel and flow into the reservoir behind the earthfill dam which would be approximately 6 miles north of Nellis Air Force Base, as described in subsection 3.01(k). The water would then flow via a 2-mile pipeline to an energy dissipating station which would dissipate 500 feet of energy and then enter a regulating reservoir having a storage capacity of 12 hours. The water would then pass through the treatment plant where it would be filtered and chlorinated before it entered the lined and covered terminal storage reservoir at elevation 2,500 feet. The water would move from the covered reservoir through 6 miles of pipeline to the aqueduct terminus at Mile 101 which would be at Elevation 2000 feet. The aqueduct terminus would be approximately 6 miles from downtown Las Vegas. At this point, it has been assumed that the water would enter a distribution system of the Las Vegas Metropolitan subarea.

Total project right-of-way requirements have been amount of water in the upper 100 feet of saturated material, or 4,900,000 acre feet. In addition, 25,000 acre feet per year of the 52,000 acre feet per year has been assumed available for export.

3.05(b) Life of Project

When the assumed water requirements of the Las Vegas Metropolitan subarea and the aqueduct capacities have been considered, the total amount of water available for export from Railroad Valley would be sufficient to supply these needs for periods in excess of the arbitrary 50-year maximum aqueduct life described in subsection 3.02(b). Therefore, the project life for the Railroad Valley facility for both the high and low projected growth rates has been taken as 50 years.

3.05(c) Description of Aqueduct Facilities

The aqueduct from Railroad Valley to the Las Vegas Metropolitan subarea would have a total length of 210 miles which may be categorized into 62 miles of trapezoidal channel, 144 miles of pipeline, 3 miles of tunnel, and 1 mile of reservoirs. The aqueduct would begin in Railroad Valley, cross the Quinn Canyon mountain range, the Timpahute mountain range and the North Pahranagat range on its way to the Las Vegas Valley. The Railroad Valley aqueduct would be unique in a number of features. For instance, it would be the largest of the intra-state water transfer plans. It is the only plan which incorporates a power plant, it is the only plan which has two tunnels and it would be the most costly to construct.

The aqueduct would begin in Railroad Valley at a point which is approximately 18 miles due south of the town of Current at an elevation of 5,000 feet. The first 35 miles of the aqueduct would constitute the collection system. The collection channel generally would follow the 5,000 foot contour as shown on Plate 1. Commencing at mile 35, the water would flow through 17 miles of open channel to the pumping station forebay which would have a 24-hour storage capacity. The water would be lifted from the pumping station forebay 900 feet through a 12-mile pipeline to a reservoir at elevation 5700 which would have a 4-day storage capacity. The required horsepower of the pumping station to accomplish this task would be 43,500 or 27,000 horsepower for the high and low projected rate of growth respectively. The water would then flow through 38 miles of pipeline and then 2 miles of tunnel to a reservoir of 24-hour storage capacity at elevation 5360. From the reservoir the water would begin its 1,440-foot descent into the Pahranagat Valley where it would pass through the power plant. It would be capable of producing 36,000 or 22,000 kilowatts of energy for the projected high and low rates of growth. An interesting feature of this plan is that the available head for power is 1,440 feet and the total lift required is only 1,250 feet. Theoretically, once it has been started, this system would sustain itself indefinitely.

From the power plant afterbay the water would flow through a 10-mile open channel past the town of Alamo to a 12-hour storage reservoir which also would serve as the pipeline inlet facility. The water would then continue its journey through 77 miles of pipeline to a 1-mile tunnel from which it would flow into the large reservoir created by an earth fill dam located 6 miles north of Nellis Air Force Base as described in subsection 3.01(k)3.

The water would then flow via a 2-mile pipeline to an energy dissipating station which would dissipate 500 feet of energy and then enter a regulating reservoir having a storage capacity of 12 hours. Passing through the treatment plant the water would be filtered and chlorinated before it enters a covered reservoir which would serve as the terminal reservoir at an elevation of 2,500 feet. The water would move from the covered storage reservoir through 6 miles of pipeline to the aqueduct terminus at Mile 210 which is at elevation 2,000 feet. The aqueduct terminus would be approximately 6 miles from downtown Las Vegas. At this point it has been assumed that water would enter a distribution system of the Las Vegas Metropolitan subarea.

Total project right-of-way requirements have been estimated at 5,400 acres of which 200 acres are privately owned, the remaining 5,200 acres being owned by units of local, state or federal government. Right-of-way costs have been assumed to average $500 per acre and are included in construction costs.

3.05(d) Cost of System

The total estimated capital cost of the aqueduct facilities from Railroad Valley to Las Vegas Valley is $473,973,000 and $372,446,000 for the high and low growth rates respectively. These estimates include an amount of $1,680,000 for the purchase of farms and associated water rights in Railroad Valley as discussed in Subsection 3.05(e). A breakdown of these capital costs is given in Figure III-8. The annual operation and maintenance costs of the project have been estimated as follows:

ITEM	Q = 350 cfs	Q = 216 cfs
Annual Power Costs	$1,569,000	$ 736,000
Treatment Plant Operation	1,490,000	1,080,000
Operation, Maintenance and Replacement	1,930,000	1,520,000
Total Annual Cost of Operation and Maintenance	$4,989,000	$3,336,000

The low power costs of this plan may be attributed to the fact that the bulk of the power is produced by the estimated at about 3,600 acres of which 340 acres are privately owned. The remaining 3,260 acres are owned by units of local, state and federal government. Right-of-way costs have been assumed at an average coat of $500 per acre and are included in the construction costs.

3.06(d) Cost of System

The total capital cost of the aqueduct facilities from Pahranagat to Las Vegas Valley has been estimated to be $245,982,000 and $192,360,000 for the high and low growth rates, respectively. These estimates include $6,600,000 for the purchase of farms and associated water rights in the Amargosa Valley as discussed in Subsection 3.06(e). A breakdown of these capital costs is given on Figure III-9.

The annual average operating costs of the project have been estimated as follows:

ITEM	Q = 350 cfs	Q = 216 cfs
Annual Power Costs	$ 647,000	$ 596,000
Treatment Plant Operation	1,050,000	965,000
Operation, Maintenance and Replacement	1,030,000	800,000
Total Annual Cost of Operation and Maintenance	$2,727,000	$2,361,000

The total annual cost of the system is the sum of the total annual cost of operation and maintenance and the amortized capital cost and has been estimated to be $23,527,000 and $18,031,000 for the projected high and low growth rates. Since average deliveries over the life of the project would be 110,000 and 101,000 acre feet per year, the resulting unit cost of water would be $214 and $178 per acre foot respectively. This information has been summarized on Figure III-9.

3.06(e) Effects on Pahranagat Valley If System Implem ented

3.06(e)1 Farming. Again, in the case of this project as in the others, the principal effect would be to end agriculture in the valley. About 6,000 acres are currently irrigated. The only town of size, Alamo, has a population of only about 300. The value of land is not complicated by any prospects of immediate urban use. Over the next 50 years, Alamo might become a commuter town for the Las Vegas Metropolitan subarea. However, it is 100 miles away and the present highway is not designed for heavy use. No real estate subdividing has been attempted. The value of the land must rest strictly on its agricultural use. There are 11,000 acres with water rights that would have to be purchased. An equitable value for an average acre would appear to be $500. Again, allowing 20 percent for various acquisition costs, total reparation costs would be $6,600,000.

3.06(e)2 Total Economic Impact. The town of Alamo has a minimal amount of service activity almost all of which is directed at travelers. There are no local firms that service agriculture.

3.06(e)3 Other Considerations. For motorists travelling along U.S. 93, the Pahranagat Valley's agriculture provides a welcome interlude of about twenty miles of green, beautiful, tree and lake filled roadside in contrast to the desert. The impact of the Project would be to dry up this area and make it less attractive. Since the economic future of Nevada is thought largely to lie in the field of tourism, the drying up of the Pahranagat Valley would be a detraction from what is required to make desert country interesting. One of the principal northerly thoroughfares from Las Vegas would be made less interesting for tourists.

Drying up of the Pahranagat Valley would also adversely effect the State Fish and Game Refuge at Hiko and the Federal Wildlife Refuge at the south end of the Valley. The damage involved in the drying up of the valley's environment is not one upon which a monetary value can be placed nor is there anyone to whom reparations should be specifically paid. The losers would be the many people who would travel through this very enjoyable area of the state.

As discussed in subsection 2.01(g)2, heavy pumping in Pahranagat Valley could affect the down gradient ground-water basins including that of the upper Moapa Valley and the springs which provide most of the flow in the Muddy River.

3.06(e)4 Subsidence. For a discussion of subsidence, refer to subsection 3.03(e)4.

3.07 VIRGIN RIVER

The Virgin River flows from Utah, through Arizona, and into Nevada. On its journey to Lake Mead the Virgin River passes within 53 miles of Las Vegas. When a supplemental water supply for Las Vegas is considered, it is natural to investigate the possibility of the Virgin River. Unfortunately, the water of the Virgin River is of poor quality, flows erratically, and is insufficient in quantity to supply the Las Vegas area.

3.07(a) Amount of Water Available

The U.S. Geological Survey (19) has estimated the long term system yield of the Virgin River at 123,000 acre feet per year. If the Dixie project is constructed near St. George, Utah, it would divert 61,600 acre feet of water, the amount of water then available for export would be reduced to about 60,000 acre feet per year. Since the deficit in the Las

Vegas Metropolitan subarea for the high and low growth rates would be 211,000 acre feet and 131,000 acre feet per year near the end of the study period, it can be seen that the Virgin River would not be capable of supplying the entire deficiency.

3.07(b) Water Quality

From a quality standpoint the water in the Virgin River would require extensive treatment in order to be improved to the quality of the water to which Las Vegas is accustomed. For instance, there are 3.6 times the concentration of sulphates, 1.4 times the concentration of chlorides, and 4.3 times the concentration of total dissolved solids as recommended in the Public Health Service, 1962 Drinking Water Standards.

3.07(c) Erratic Flows

A third problem associated with the use of the Virgin River for a water supply for the Las Vegas Metropolitan area is the erratic nature of the Virgin River flows. Flow rates for the Virgin River have been estimated from a minimum of 40 cfs to a maximum of 40,000 cfs. The problem with using water from such an erratic source is that conceivably approximately one half of the flow of the Virgin River in any year may occur during a one-or two-week period of heavy rainfall or snowmelt. If this water is to be stored so that it may be delivered to the area which it supplies, as needed, it would be necessary to construct a dam which would be capable of impounding approximately one half of the annual flow. For the Virgin River, this would result in a reservoir having approximately 60,000 or 30,000 acre foot storage capacity. Although the Bureau of Reclamation has studied the Virgin River in connection with the Dixie Project, no dam sites of quality have been found between Littlefield, Arizona and Lake Mead.

3.07(d) Cost of Importing by Pipeline

The final problem which must be faced when considering the Virgin River as a water supply is that its water must still be transported 53 miles to Las Vegas. Since the elevation of the river is approximately 1,200 feet, this would require that the water be lifted approximately 1,300 feet. Inspection of the several alignments possible for an aqueduct has disclosed that almost none of the alignments is conducive to the construction of canals which are cheaper than pipelines. Therefore, the cost of the pipeline from the Virgin River to Las Vegas would be approximately equivalent to the cost of the aqueduct from Pahrump to Las Vegas. To this must be added the cost of a dam and the cost of desalinization. It can be seen without making a complete economic investigation that the water from the Virgin River would be more costly and therefore, not competitive with water from Pahrump and Pahranagat.

3,07(e) Credit to Nevada's Colorado River Allotment

The Virgin River originates in Utah, flows through Arizona, and enters Lake Mead and hence the Colorado River mainstem in Nevada. Since the United States Supreme Court has held that the Lower Basin States are entitled to exclusive use of the tributaries of the Colorado River within each State the possibility exists that an entitlement could be obtained for the surface and subsurface inflow to the mainstem of the Colorado River from the Virgin River Valley. This combined outflow to Lake Mead is estimated to be on the order of 123,000 acre feet annually, two-thirds being surface water and one-third ground water. By claiming that the introduction of Virgin River Valley water into Lake Mead creates an entitlement by the State to increase diversions of water from the mainstem of the Colorado River over and above the 300,000 acre feet apportioned to Nevada, the State might use Lake Mead as a conduit and divert the subject tributary water from the Lake at any convenient location. The quality of water would be greatly improved by its being blended with Lake Mead water.

The cost of transporting the water to Las Vegas would be reduced because the water would be transported 40 of the 53 miles by Lake Mead. Although the Virgin River flows still are admittedly inadequate to fulfill the entire deficit of the Las Vegas Metropolitan subarea, its consideration as a partial supply is warranted by the lower unit costs of the water.

3.07(f) Cost of Importing Through Facilities Parallelling SNWP Facilities

The cost of the system to import the 123,000 or 61,000 acre feet of water assumed available from the Virgin River has been prepared by updating the average cost of importing a unit of water through the first stage of the Southern Nevada Water Project facilities. It has been estimated by others that the 50-year average cost of treated water will be about \$35 an acre foot. Of this total unit price approximately \$13 an acre foot represents operation costs and approximately \$22 per acre foot represents the capital costs associated with the delivery of the "typical" acre foot of water.

The \$22 per acre foot representing capital costs has been updated to reflect current construction costs and to reflect an interest rate of 7 percent rather than the 3-1/4-percent rate used for the SNWP. The resulting unit cost of water would be \$63 per acre foot.

This estimated cost has assumed that a separate system paralleling the SNWP facilities would be constructed. However, sizeable reductions in the overall construction cost and hence the unit cost of water, may be possible if the SNWP facilities were to be enlarged to transport this additional Virgin River water. Therefore, the $63 per acre foot is conservatively high.

In summary the Virgin River represents a reasonable source of supply for the Las Vegas Metropolitan subarea if Lake Mead may be used for dilution and as a vehicle to transport the water some 40 miles closer to Las Vegas.

3.08 COMPARISON OF INTRASTATE IMPORTATION PLANS

A summary of the five plans for the intrastate transfer of water is shown below. The unit costs shown do not include water system distribution expenses. These expenses have been estimated at $65 per acre foot for the Virgin River system and $62 for the other systems. The higher amount for the Virgin River system is due to the lower hydraulic grade line at which the SNWP aqueduct terminates.

A comparison of these costs to the retail cost of water sold by the Las Vegas Valley Water District is of interest. The average cost of all water sold in fiscal year 1970 was $90 per acre foot.

A comparison between these intrastate water transfer plans and some interstate plans is presented in Subsection 8.05.

TABLE III–1

ESTIMATED WATER COST AND PROJECT LIFE OF INTRASTATE IMPORTATION PLANS

	High Growth Rate			Low Growth Rate		
	Unit Cost			Unit Cost		
Source	Production $/AcFt	Production & Distribution $/AcFt**	Length of Supply Years	Production $/AcFt	Production & Distribution $/AcFt**	Length of Supply Years
LVVWD (1970)	26	90	-	26	90	-
Virgin River*	63	128	50	63	128	50
Pahrump Valley	186	248	33	168	230	39
Pahranagat Valley	214	276	26	178	240	29
Amargosa Desert	270	342	27	225	287	30
Railroad Valley	252	314	50	268	330	50

* Virgin River will not supply the entire anticipated water shortage for the high or low growth rates.
** Cost to ultimate consumer

IV PART 2
SUPPLEMENTAL WATER SOURCES OUTSIDE NEVADA

SUPPLEMENTAL WATER SOURCES OUTSIDE NEVADA

4.01 GENERAL

In addition to solving southern Nevada's water problems with available water from within the state, several possibilities exist for meeting the future water requirements with water imported from out-of-state areas. During the past decade, several far-reaching proposals for solving the water problems of the southwestern and western states were presented for consideration. Many of these plans proposed supplying imported water to Lake Mead and hence could be considered as possible solutions to southern Nevada's projected water shortage. One of the earliest plans, the Pacific Southwest Water Plan, as proposed by then Secretary of Interior, Stewart Udall, was the catalyst which spurred the rash of plans that were subsequently developed. For the purposes of this study, several of the plans which followed the Pacific Southwest Water Plan and which also appeared to be reasonable alternatives to the intrastate water plans have been revised to the same economic basis as the intrastate plans in order to obtain a viable cost comparison.

None of the interstate (regional) importation plans have been studied in depth. The comparison has been limited to a review of these plans and an adjustment of the cost figures to reflect those economic conditions which have been used in computing costs for the intrastate plans. Hence, construction costs have been increased to the 1970 levels; and a 7 percent interest rate has been used to recompute the annual costs and unit costs of the interstate plans. The recomputed costs have been compared to the unit costs for the intrastate plans to determine if the intrastate plans would favorably compare on an economic basis. The effect of different interest rates on the price of interstate water can be determined approximately by referring to subsection 3.02(c).

At this point it should be mentioned that the intrastate and interstate plans cannot be compared on an equal basis. It is possible in most cases to compare them economically, but there is an essential difference between them with reference to Nevada. The intrastate plans may be implemented by authority of the state or political subdivisions of the state; however, the interstate plans need the cooperation and approval of other states. Since the interstate movement of water is a very sensitive topic, especially to those states that provide the source of the diversions, the implementation of an interstate water plan can be a difficult task. Hence, even though a particular interstate water plan may show a more economical unit cost of water when compared to the intrastate plans, the implementation of that plan is beyond the authority of the State of Nevada. For this reason, it may be necessary to proceed with a less economical intrastate plan in order to meet the water requirements of a water-deficient area rather than wait on an interstate plan that may take so long to put into operation that an extensive period of water shortage develops.

It should be emphasized that all of the interstate water importation plans are very broad and far-ranging and were not prepared in detail. Consequently, they are somewhat vague and unrefined in many respects. Because of this, it is possible that the approximations found in these plans may need to be refined and corrected to a considerable degree before a dependable cost determination for each plan can be made.

4.02 NAWAPA AND THE PACIFIC SOUTHWEST WATER PLAN

Two previous plans which involved supplying the southwest with imported water were the NAWAPA and the Pacific Southwest Water Plan. NAWAPA (North American Water and Power Alliance) is a continental plan which calls for diversions from parts of Alaska and Canada to supply extensive sections of Canada, the United States, and Mexico. The Pacific Southwest Water Plan proposes to divert water from northern California and transfer it to southern California and Arizona. The NAWAPA plan is very broad and involves three countries. This plan proposes to take 110-million acre feet per year from rivers in undeveloped areas of Alaska and Canada and transfer it to an enormous reservoir in northern Montana and southern Canada. From this 507-million acre-foot reservoir, water would be transported to the prairie lands of southern Canada and ultimately to Lake Superior. In addition, a connection on the southern end of the reservoir would provide an exit for water to be transported to southwest United States and northern Mexico.

SUPPLEMENTAL WATER SOURCES OUTSIDE NEVADA

Because of the large scale of NAWAPA, many obstacles stand in the way of implementing the plan. Since this plan would involve taking a large supply of Canadian water to supply deficient areas in southwestern United States and northern Mexico, many objections to the plan have been raised by the Canadian people and government. Besides removing a portion of the Canadian fresh-water resources from the country, NAWAPA would also inundate much Canadian land with reservoirs and waterways.

Since this plan has met with serious opposition, it is doubtful that this plan or any other continental water plan could be implemented in time to alleviate the projected water shortage of southern Nevada. Given the eventuality of an agreement between all interested parties, it would still be doubtful that the physical facilities could be constructed in time. Hence, no cost comparisons have been made between NAWAPA and the intrastate plans.

The Pacific Southwest Water Plan is a regional water supply plan; and, therefore, involves fewer concerned parties than NAWAPA. This plan proposes to divert 1.2 million acre-feet per year from northern California and transport this water to the Sacramento River. From the Sacramento River delta area a canal would take the water southward to southern California. The 1.2 million acre-foot per year diversions proposed in the Pacific Southwest Water Plan would be used to provide a guarantee to the Lower Basin States of the Colorado River. This importation would guarantee that the Lower Basin States would receive their 7.5-million acre-foot per year share of the flow in the mainstem of the River and that Nevada would be guaranteed its allotted share of 300,000 acre-feet per year. The Southern Nevada Water Project would provide the conveyance facilities necessary to take Nevada's share from Lake Mead. However, the water shortage projections for southern Nevada have been made in this study on the assumption that that 300,000 acre-foot per year supply would be available; and, so even with this supply, southern Nevada is projected to face a water shortage near the end of this century.

Since the Pacific Southwest Water Plan does not furnish the necessary amount of additional water to southern Nevada to offset its projected water shortage, the plan has not been considered on an economic basis with the intrastate water plans. Both NAWAPA and the Pacific Southwest Water Plan have been mentioned here because they are two of the most well-known water importation plans. However, neither appears to be able to solve the shorter range water deficits which are projected for southern Nevada.

4.03 SNAKE–COLORADO PROJECT

In answer to Secretary of Interior Udall's request for the development of other regional water plans, Samuel B. Nelson, then of the Los Angeles Department of Water and Power, presented the Snake-Colorado Project (20) for consideration in 1963. This proposal calls for diverting 2.4 million acre-feet per year from the Snake River and transporting it to Lake Mead. The total length of conveyance to Lake Mead would be 519 miles, and the total lift would be 3,183 feet. From Lake Mead the imported water could be diverted directly or allowed to flow by gravity to Lake Havasu for diversion.

The economic analysis as presented in Nelson's Snake-Colorado Project indicates that the unit cost for delivery of the 2.4 million acre-feet per year to Lake Mead would be $32 per acre-foot. In computing this unit cost, Nelson used a 3 percent interest rate on capital investment, an amortization period of 100 years, and 1963 construction costs. In order to adjust the unit cost to an economic basis comparable to the intrastate plans, the interest rate has been changed to 7 percent and construction costs have been changed to 1970 values. A 100-year amortization period has been used in recomputing the unit costs. For a large scale project such as a regional water plan, it is believed probable that federal financing with a long-term repayment period could be arranged. Since this could not be assumed for the intrastate water plans, a shorter amortization period has been used for those plans.

The adjusted unit cost for water in the Snake-Colorado Project has been determined to be $112 per acre-foot, which includes a factor of 55 percent of the construction costs to cover the contingencies, engineering, financing, and administration. This factor has also been applied to the unit costs for the intrastate plans. A further cost to be added is the cost of transferring the water from Lake Mead to the Las Vegas area and treating it. As described in subsection 3.07(f), the unit cost of transferring and treating the water would be $63 per acre foot. This cost is based on using Lake Mead as the terminal storage site for the imported water and transporting water from Lake Mead to Las Vegas through an aqueduct sized to deliver 135 percent of the average annual demand. Instead of routing the imported water through Lake Mead, it is possible that a connection to the Snake River-Lake Mead Aqueduct could be made along the route so as to reduce the cost of transferring the water to Las Vegas; however, for this analysis, the water has been assumed to be taken from Lake Mead.

Based upon the above assumption, the total unit cost for importing water to Las Vegas through the Snake-Colorado Project has been computed to be $175 per acre foot. This unit cost is on a comparable economic basis with the unit costs for intrastate plans.

4.04 MODIFIED SNAKE–COLORADO PROJECT

SUPPLEMENTAL WATER SOURCES OUTSIDE NEVADA

The Modified Snake-Colorado Project (21) as developed by William G. Dunn is a modified version of Nelson's Snake-Colorado Project. In August of 1964, when Dunn's plan was before a joint Senate-Assembly Committee of the California State Legislature, the objectives of the plan were to divert 5-million acre feet annually from the Snake River and transport the water to Lake Mead. However, Dunn later revised his original plan to include a total diversion of 15-million acre-feet per year from the Columbia River at the mouth of the Snake River and from various locations along the lower Snake.

Dunn's revised plan of 1965 is claimed to be capable of providing eleven western states with adequate water supplies for a period of 50 to 60 years. The central feature of the plan is the Snake-Colorado Aqueduct, a 1,016 mile-long north-south canal extending from Brownlee Reservoir on the Snake River, the collection point for all water diverted from the Snake and Columbia Rivers, to Lake Mead.

Three branch aqueducts would be included to provide water for parts of Idaho, Oregon and California. These aqueducts would be part of later phases of development. The initial phase would include construction of the Snake-Colorado Aqueduct with diversions of 5-million acre-feet annually. The second and third phases, constructed at 15-year intervals, would include the three branch aqueducts to Idaho, Oregon and California. With construction of the third phase, total annual diversions from the Snake and Columbia Rivers would reach 15-million acre feet.

In Dunn's "Statement on Modified Snake-Colorado Project (Dunn Plan)" of October, 1965 (21), an economic analysis of the first phase indicates that the unit cost of water would be $37.60 per acre foot. This cost estimate was based on 1965 construction costs, a 3 percent interest rate, and a 100-year amortization period. Net annual cost with interest and amortization for the first phase was shown to be $188,000,000.

In order to compare the unit cost of this plan with those for the intrastate water plans presented earlier, Dunn's costs have been recomputed to reflect 1970 construction costs and a 7 percent interest rate. With these conditions the unit cost for delivering water to Lake Mead in Dunn's plan has been computed to be $128 per acre foot. As before, this unit cost has been increased to include the 55 percent contingency factor. By including $63 per acre foot for treating and transporting the water from Lake Mead to Las Vegas, the total production cost would be $191 per acre foot.

4.05 SIERRA–CASCADE PROJECT

In the summer of 1964, E. Frank Miller presented his version of a regional water plan to serve the Pacific Southwest (22) . This plan is larger in scope than the Pacific Southwest Water Plan and the Snake-Colorado Project, but it is much smaller than NAWAPA. Miller proposed to divert Columbia River water from below Bonneville Dam near Portland, Oregon, and through a series of pumping stations, reservoirs and aqueducts to transport the water to Warner Valley, a natural storage site in the vicinity of the state boundary intersection of Oregon, Nevada and California. From this 75-million acre-foot capacity reservoir, water could be transferred southward to Walker Lake in west-central Nevada and then to Lake Mead. Diversions from the Warner Valley-Lake Mead Aqueduct are envisioned to transfer water to the Pit River in northern California and the Owens River in southeastern California.

Miller developed three alternative rates of supply to the Warner Valley storage site and three alternative distribution schemes from Warner Valley. The three rates of supply to Warner Valley are 7.5, 15,0, and 30-million acre-feet per year. The three distribution schemes are: (1) to convey 7.5-million acre-feet per year to Lake Mead; (2) to convey 7.5-million acre-feet per year to Lake Mead and 3.75-million acre-feet per year to both the Pit River and Owens River; and (3) to convey 15.0-million acre-feet per year to Lake Mead and 7.5-million acre-feet per year to both the Pit River and Owens River.

In Miller's Sierra Cascade Project, an economic analysis is presented for the various conservation (storage) rates and distribution schemes. Inspection of this cost analysis has revealed that Miller's unit costs could not easily be adapted for direct comparison with the intrastate plans and to have done so would have involved an extensive study beyond the scope of this report. For this reason, an economic comparison has not been made between this plan and the intrastate plans.

4.06 DESALINIZATION

In recent years advancements in technology related to desalinization plants have enabled larger and more economical plants to be constructed. With continuing technological advance, desalinization plants have come progressively closer to competing on an economic basis with other forms of water supply. In order to investigate the feasibility of using such a plant to alleviate southern Nevada's projected water shortage, an economic analysis has been performed to determine the suitability of siting a desalinization plant on the Pacific Coast near Los Angeles. In this example, the plant would be used to supply the Metropolitan Water District of Southern California (MWD) with good quality, treated sea water in exchange for a share of MWD's allocation of Colorado River water. The analysis which follows indicates that while the desalinization plant is not the most economical alternative, it is competitive with the other water supply plans.

The material upon which the economic analysis has been based has been taken from the review draft of a report to be published by the Office of Saline Water (23). The costs of the various components of a desalinization plant, which were listed in the Office of Saline Water Report, have been altered to represent a 7 percent interest rate, as done in the preceding economic analyses of the interstate water plans. The amortization rate has been set at 30 years which is the expected lifetime of a desalinization plant. Additional economic and physical parameters which were used in the analysis and which are not given here may be found in the Office of Saline Water Report.

The economic analysis as described below has been performed for a 122-mgd water (desalting) plant with a dual purpose nuclear power plant. This plant would be located along the Pacific Coast within approximately 25 miles of an MWD connection. Conveyance facilities to the MWD system would be provided in addition to the desalting and power plants. Costs associated with this phase of the desalinization project include the costs of constructing, operating, and financing the desalting and power plants and the conveyance facilities and costs of land acquisition. The other phase of the project would involve transportation of Colorado River water from Lake Mead to the Las Vegas area.

Table IV-1 is a summary of the costs which could be expected to accrue from this project. The costs shown under water, steam, and power were obtained by altering the figures given in the Office of Saline Water Report (23) to reflect a 7 percent interest rate. In altering the steam and power unit costs, it has been assumed that 30 percent of the unit cost figures are a result of capital costs. These costs have also been updated to 1970 construction cost levels by using the appropriate ENR construction cost index ratio. Total unit cost of the first phase of the project is expected to be $149 per acre foot for treated water delivered to the MWD.

The land interest item on the cost table has been computed by assessing a 7 percent interest rate on the cost of land acquisition. Total land to be acquired for the water plant and power plant has been determined to be 250 acres as indicated by Fig. 2.2 of the Office of Saline Water Report. A cost of $100,000 per acre was assumed for the plant site since it would be situated on beach property in the southern California area. Since the cost of land acquisition ($25,000,000) could be recovered at the end of the plant life, only the interest charges affected the unit cost.

The item listed as the unit cost for conveyance to MWD is the cost for pipelines and pumping stations required to transport the desalted product water from the plant site to the MWD system. A distance of 25 miles has been assumed for this pipeline. This cost estimate has been based upon estimates prepared by the Bureau of Reclamation Office in Boulder City. As above, the cost estimates have been altered to reflect a 7 percent interest rate and a 30-year amortization period.

The second phase of the project would involve treating and transporting the water from Lake Mead to the Las Vegas area. As previously described, the unit cost for transporting and treating the Lake Mead water has been estimated to be $63 per acre foot.

TABLE IV–1

SUMMARY OF COSTS–DESALINIZATION PLAN
(122-mgd water plant with dual-purpose nuclear power plant)
(1970 construction costs)

	UNIT COSTS	
Water	¢/1000 gal	$/AcFt
Fixed charge @ 8.767%[1]	15.9	
Chemical cost	3.7	
O&M, labor and material	2.2	
Interim replacement @ 0.35%	0.6	
Steam		
Public financing - 1980[2]	10.3	
Power		
Public financing - 1980[2]	1.8	
Unit Cost (desalting only)	34.5	$112.40
Land Interest (7%)		15.90
Conveyance to MWD		20.90
Total Unit Cost (First Phase)		$149.20
Conveyance to Las Vegas from Lake Mead		63.00
Total Unit Cost (First & Second Phases)		$212.20
Reparations from MWD		
Savings in operation costs (Colorado River acqueduct)		7.70
Savings in treatment costs		4.00
NET UNIT COST ($/AcFt)		$200.50

1. Includes 7% interest on capital funds, 30-year plant lifetime, 0.8% insurance cost
2. 7% interest on capital funds, 30% annual costs = capital costs, 30-year life

As shown in Table IV-1, the total unit cost for this project is expected to be $212.20. However, it is reasonable to expect a reduction in this unit cost through reparations made by the MWD for savings it realizes from the project, Because this alternative water plan would involve a treated-water delivery directly into the MWD system, two savings would result from a reduction in the scale of operations of the Colorado River Aqueduct. The first has been estimated to be $7.70 per acre foot on the basis of information given in the Snake-Colorado Project. The second savings would arise from the fact that the MWD would receive treated water instead of untreated Lake Mead water. Hence, a savings in treating the water would be realized. This savings has been estimated to be $4.00 per acre foot.

The savings realized by the MWD should be considered as credit in the cost analysis; hence, the total credit of $11.70 per acre foot has been subtracted from the total unit cost to arrive at a net unit cost of about $200 per acre foot for the desalinization alternative.

4.07 EFFECT OF UPDATING UNIT COSTS OF REGIONAL WATER PLANS

As indicated in the preceding paragraphs, the unit costs of the interstate water plans more than double when they are adjusted to reflect a 7 percent interest rate and 1970 construction costs. Table IV-2 lists the various increasing unit costs for the Snake-Colorado and the Modified Snake-Colorado Projects, the two projects which have been put on a comparable economic basis with the intrastate plans. The last column of this table lists the expected total unit costs for water delivered but not distributed to the Las Vegas Metropolitan Subarea for each plan at a 7 percent interest rate on all capital investments and 1970 construction costs.

In computing the total unit costs, no allowance has been made for an increase in operation, maintenance, and replacement (OM & R) costs. This has been done because of the wide variance among the various proposals in methods of computing such items as power revenues, power costs, and other entries of the cost analysis other than capital costs. In essence, this means that while the total unit costs shown in Table IV-2 are on a somewhat comparable economic basis with one another and with the intrastate plans, they should be further refined to put OM & R costs on an equal economic basis before they can be exactly compared. This extensive additional work is outside the scope of this report, since the purpose of studying these regional water plans has been to obtain only an order-of-magnitude comparison of the unit costs of these plans with those of the intrastate plans.

The importance of changing the interest rate and construction costs when determining unit costs for a water plan is illustrated in Table IV-2. For the Snake-Colorado Project, the unit cost increased over 140 percent from its 1963 estimate. The effect of increasing the interest rate and construction costs as dictated by the prevalent economic conditions should be clearly understood before attempting to compare plans which were developed at different times. Unless the unit costs are put on a somewhat comparable economic basis, a comparison of even the order of magnitude of various unit costs would be meaningless.

TABLE IV–2

ORIGINAL AND ADJUSTED UNIT WATER COSTS OF INTERSTATE PLANS

Water Plan	Original Unit Cost	Unit Cost Adjusted to 1970 Costs & 7% Int.	Unit Costs with Contingencies Added*	Unit Cost with Treatment & Transportation to Las Vegas Added
Snake-Colorado (1963)	32	77	112	175
Modified Snake-Colorado (1965)	38	88	128	190

* The additional 55% for contingencies, engineering, legal, administrative, and financing costs.

Table IV-3 indicates the adjusted unit costs of the three interstate alternatives considered in this report. An amount of $65/ac.ft. has been added to the previously computed costs to arrive at the estimated average cost to the consumer. This $65/ac.ft. represents the cost of distributing the water to the consumer from the aqueduct terminus. As shown in the table, the three units costs all are approximately the same. Because the values are so close and because of their approximate nature, it would be unwise to classify one as the most economical on the basis of these unit costs.

TABLE IV–3

ESTIMATED UNIT WATER COST OF INTERSTATE IMPORTATION PLANS

Plan**	Unit Cost Production $/Ac.Ft.	Unit Cost Production & Distribution $/Ac.Ft.=
Snake-Colorado Project	175	240
Modified Snake-Colorado Project	190	255
Desalinization	200	265

= Cost to ultimate consumer
** All plans based on utilization of Lake Mead as a terminal reservoir.

V PART 2

ECONOMIZATION OF WATER

ECONOMIZATION OF WATER

5.00 INTRODUCTION

The amount of water needed by a community is not a fixed amount per capita. United States communities vary in water consumption from as little as 50 gallons a day per capita to over 500 gallons a day per capita. Many factors are responsible for the variation. The fact that such wide variations exist suggests that if the factors affecting water consumption can be analyzed, it may be possible to change some of them so as to reduce consumption. In the case of southern Nevada, if anticipated consumption for the year 2020 could be reduced by 28 percent to 39 percent, the water shortage problem would be solved.

5.01 TREND IN WATER USE

5.01(a) Short and Long Run

Water consumption increases over a period of time in most communities chiefly because of the growth of the number of people and enterprises in the community. But consumption per water connection and per capita also rises. The household itself and patterns of living change. An increasing proportion of people live in larger homes on larger lots. Old small lot residential areas are destroyed. The larger homes not only have more water-using appliances, but they have more bathrooms and possibly also swimming pools in the case of the homes of the upper income groups. More important, the larger homes are likely to be on larger lots with more irrigable area and more shrubs and trees that require water.

5.01(b) Determinants of Household Water Consumption

Household water consumption is best thought of as consisting of two distinct parts, since there are some determinants which are peculiar to only one of the parts. The two parts are inside and outside residence use.

5.01(b)1 The Inside Consumption of Water. This demand is a function of the following variables which are listed in order of relative importance.

Income or wealth of family. The higher the income level, the greater will be the consumption of water. While water consumption for drinking purposes and cooking may be virtually constant for all income groups, the amount of water used for bathing and sanitation will probably be related to the number of bathroom units that a family has.

Number of persons occupying dwelling. The significance of this to water consumption is obvious.

Price of water. This factor is often believed to not effect water consumption by householders. It is believed that health and sanitation needs must be satisfied and expenditures for water are only a very small part of income.

5.01(b)2 Outside Consumption of Water. The important variables effecting water consumption would appear to be different for outside use.

Area irrigated. Generally, the larger the area irrigated, the greater will be the water consumption.

Evapotranspiration. The amount of water used in yards will be dependent upon the quantity and speed with which water is evaporated and transpired by the particular plants in the yard.

Precipitation. The amount of rainfall will effect water needs. In the Las Vegas area, of course, this factor is almost negligible.

Price of water. This factor is important to outside if not inside use, and can be manipulated to bring about economy in the use of water.

5.02 WATER SHORTAGE PROBLEMS

The projected water shortage in the Las Vegas Metropolitan subarea has been viewed by some as a factor that could limit the growth of the area. This assumption does not appear reasonable. Historically, no city of size in the United States has ever stopped growing because of water limitations. Water costs are generally of such a small magnitude relative to the total earnings of a city that the cities invariably have been able to raise the money to obtain more water. Thus, it would have been a mistake to conclude in 1900 that Los Angeles, in an arid area, would never grow to a population of seven million because limited water resources would restrict its size.

Even if it is assumed that new water resources are simply not permitted to a city, its growth could nevertheless continue if it organized a more effective use of the existing water resources by curtailing uses which were of low importance to its development and by providing such water to more important uses. Water shortages somehow will be met. The question is merely what is the most effective (that is, the least costly) method of meeting them.

To illustrate the matter, Las Vegas can be envisioned as eventually facing a water shortage. This shortage would be different than the water crises some American communities experienced in recent decades. The recent water crisis in New York City arose from an inadequacy of water supply due to adverse variations in weather and precipitation with a resultant exhaustion of water storage supplies. In contrast, the type of water shortage which Las Vegas would experience would arise from a continuously increasing demand brought about by population growth.

The problem would be how to limit the water consumption to the amount of water available. Some sort of rationing system would have to be devised. The following rationing systems can be conceived; there doubtless are others as well.

5.02(a) Rationing Mechanisms

5.02(a)1 Limitation on Hours of Water Use. Large cities in less developed countries have been known to meet water shortages by limiting the hours during which water is made available. Thus, such a system may involve allowing water to be used from 7:00 to 9:00 a.m. and from 5:00 to 7:00 p.m. Such a system is one of the very worst systems for rationing water imaginable. In addition to the great inconvenience that is imposed on water users by having to draw supplies of water in advance for the non-water period, it permits the use of water in such low value uses as maintaining lawns while restricting its more important uses relative to cleanliness.

5.02(a)2 Forbid Low Value Uses of Water. This is a system obviously preferable to limiting hours of use and has been used by many American communities in periods of water shortage. Certain uses of water are arbitrarily deemed to be low value uses, such as the demand of water for the maintenance of yards and washing automobiles. Restrictions are then instituted against the use of water for such purposes.

5.02(b) Limitations on New Water Connections

With mounting demands for water and a constant supply of water, the water purveyor may decide to refuse to make new connections to the water system. The existence of a water connection then would become an item of value. This prohibition would doubtless curtail new construction and growth. Such a method of rationing would also be undesirable in that it would permit low value uses of water to be made.

5.02(c) The Best and Usual Rationing Mechanism - A Higher Price

The consumption of most goods in our economy, except in times of price control or rationing, is restricted by the necessity of paying a higher price rather than by rationing schemes. By charging a higher price for water, the use of water like any other good is reduced and is confined only to those uses which people really consider important, as expressed by their willingness to pay a higher price to obtain it. Under such a system one could obtain all the water he could afford to buy.

To some such a system appears inequitable. Peoples' needs, it is felt, should be satisfied independently of their ability to pay. However, acceptance of this view would drive us back to some sort of rationing mechanism as indicated above, since needs could easily exceed the available supply.

In any case, different levels of need can still be recognized by differential pricing. Thus, on equity grounds a water purveyor might set high water prices for expensive residential areas and low water prices for areas in which lower income people live. If concerned with industry and growth, the purveyor might set a high price of water for residential consumption and a low price for water consumed by industrial users. Thus a society, by raising water prices, can control water consumption so as to conform to any arbitrary set of values.

More important is the fact that by means of a higher price, water shortages can be averted. A higher price for water, as for any good, restricts consumption and assures that water is diverted into its most important uses.

5.03 ALLEVIATING WATER SHORTAGE BY REDUCING CONSUMPTION

5.03(a) Introduction

Will an increase in the price of water actually reduce the amount purchased? From their writings and discussions it appears that many water purveyors believe that while an increase in price will reduce consumption it will not reduce it much. Some voice the opinion that a 10 percent increase in the price of water will hardly reduce consumption at all. Others say that possibly a 3 percent reduction in consumption would result but that within three years water consumption would be back at the old level. Some economists, on the other hand, have argued that water has a variety of uses and that while some of these uses, such as that for health and sanitation, are such that consumption would remain the same even if there were a substantial increase of 50 or 100 percent; other uses such as for irrigation are more likely to be responsive to a changing price and are quantitatively much more significant.

What is really at issue is the nature of the demand function for water. Is there some reasonable increase in price that would cause people to reduce their consumption of water considerably? The use of the word reasonable admits that there must be some responsiveness of the quantity of water consumed at some unreasonable price such as $19.00 per 1000 gallons, rather than the present reasonable price of 19 cents per 1000 gallons! Consumption would most certainly be reduced as far as yard use is concerned at $19.00 per 1000 gallons.

Currently, however, some people pay $400 per 1000 gallons for bottled drinking water and they probably do not view this as an unreasonable price. Still, even for bottled-water consumers there must be some price at which they, too, as in the case of any good, would reduce their consumption and speak of the unreasonableness of the price. Apparently the word reasonable has no objective content. What is reasonable depends simply on what one has already experienced or on what one views as likely not to affect one much. Any substantial deviation upward is likely to be viewed as unreasonable. It is that substantial deviation that may be required for the Las Vegas Metropolitan subarea, for it is the unreasonable increase that is certain to produce a substantial decrease in consumption.

5.03(b) The Demand Function

The term "demand" is generally arbitrarily reserved by economists to mean not a specific quantity nor all the complex variables bearing on what quantity of a good a person might purchase, but rather is used to designate merely the functional relationship between the price of a good and the quantity of a good purchased, all other variables assumed constant. This relationship is expected to be an inverse one. At higher prices people will substitute other goods for the good that has risen in price. On the other hand, if the good falls in price, it may be substituted for other goods.

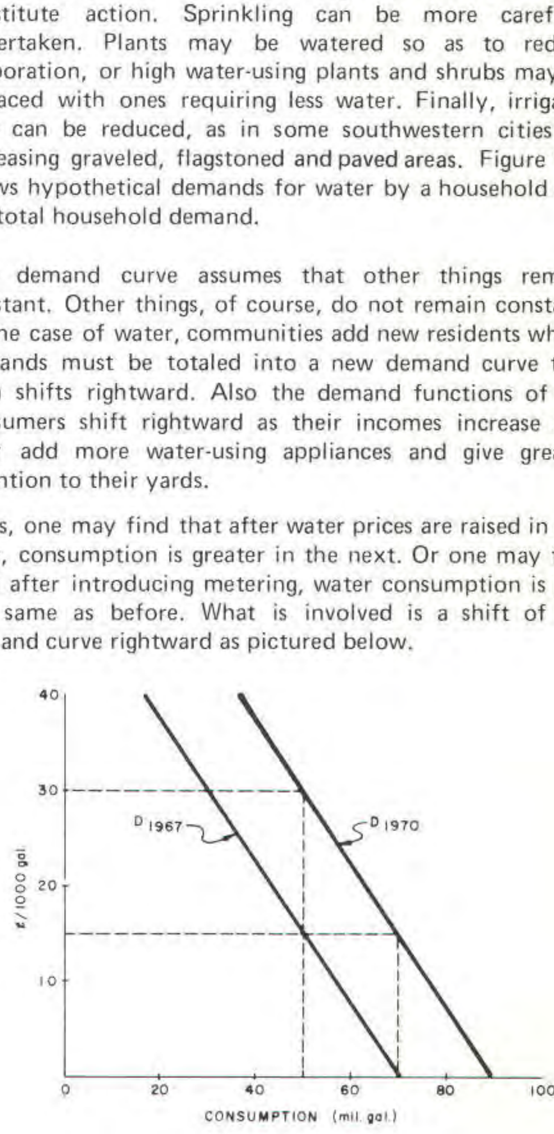
It would appear that there are no substitutes for water. Actually, however, we are considering here one specific type of water, water delivered by an urban water system. Conceivably, but unlikely, other water sources could be substituted, such as bottled drinking water or water in volume delivered by truck.

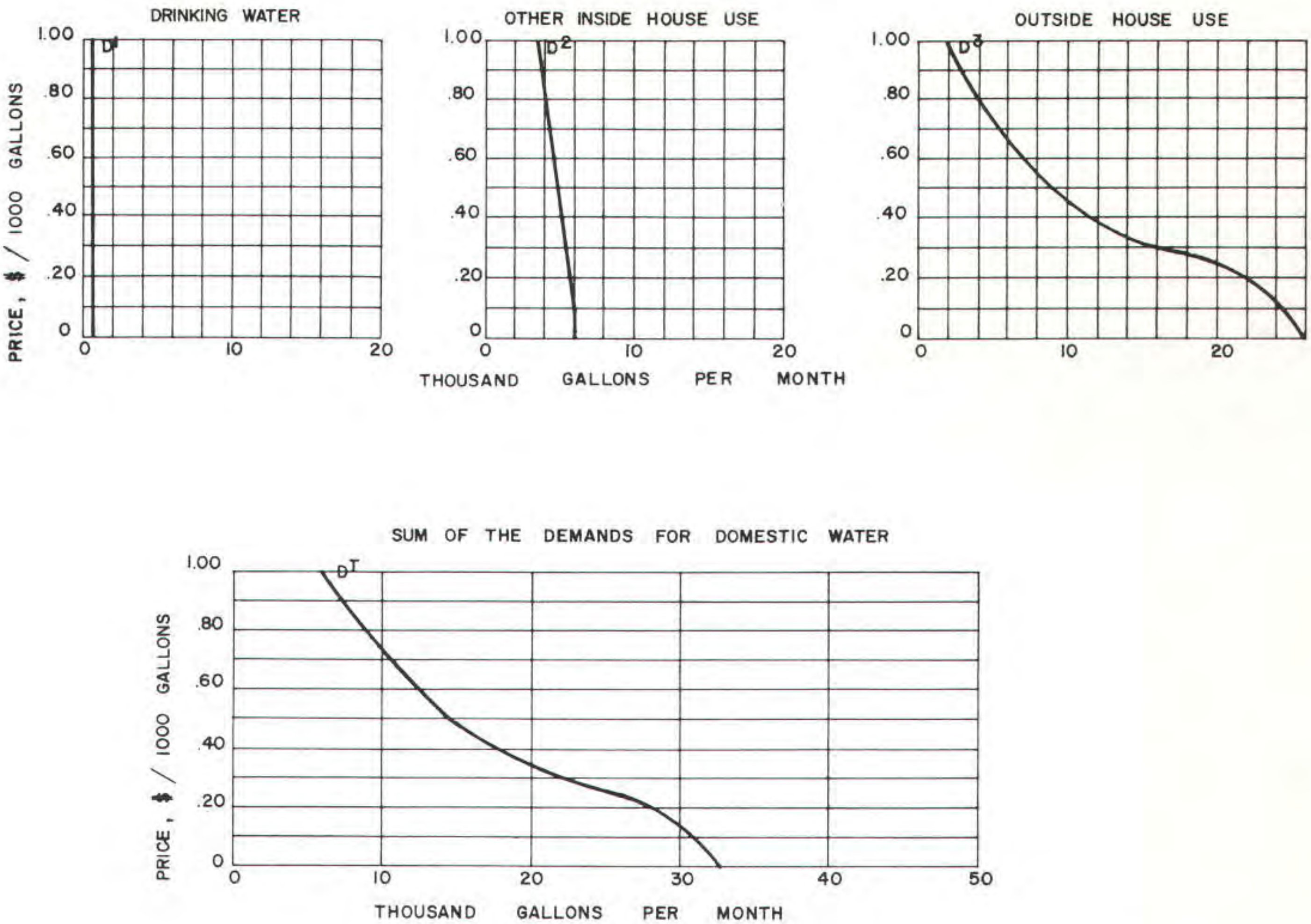
But what can one substitute for water in general? It is difficult to think of substituting other commodities for water inside the home. There are no close substitute goods like electricity for gas in cooking. Yet if one urges water economy in bathing and washing dishes one is proposing that the family substitute other goods for water. Ultimately all goods are substitutes for each other in that they compete for a share of an always finite income.

Outside uses of water present greater possibilities of substitute action. Sprinkling can be more carefully undertaken. Plants may be watered so as to reduce evaporation, or high water-using plants and shrubs may be replaced with ones requiring less water. Finally, irrigable area can be reduced, as in some southwestern cities by increasing graveled, flagstoned and paved areas. Figure V-1 shows hypothetical demands for water by a household and the total household demand.

The demand curve assumes that other things remain constant. Other things, of course, do not remain constant. In the case of water, communities add new residents whose demands must be totaled into a new demand curve that then shifts rightward. Also the demand functions of old consumers shift rightward as their incomes increase and they add more water-using appliances and give greater attention to their yards.

Thus, one may find that after water prices are raised in one year, consumption is greater in the next. Or one may find that after introducing metering, water consumption is just the same as before. What is involved is a shift of the demand curve rightward as pictured below.





HYPOTHETICAL WATER DEMANDS OF A HOUSEHOLD (FIG. V-1)

(ALL OTHER THINGS CONSTANT)

Failure to consider the demand shift above produces what may be called the ineffectiveness of meters fallacy. Namely that while meters may at first offset people's consumption, in time they are not effective, since consumption returns to the old level. In the example above, the consumption in 1967 at a price of 15 cents/1000 gallons was 50 million gallons. The price was increased to 30 cents/1000 gal and consumption 3 years later was again 50 million gallons. What is overlooked is the shift in the demand curve. If the price of water had not been increased consumption would have been 70 million gallons in 1970. Thus time series on price and consumption may mislead one as to the responsiveness of water consumption to price. Cross sectional data, rather than historical situations, better reveal the responsiveness of water consumption to difference in price. Below is given the water consumption experience of a group of metered communities as contrasted with a group of non-metered communities (24).

Use	Gallons per Day per Dwelling Unit	
	Metered Areas	Flat Rate Areas
Annual Average		
Leakage and Waste	25	36
Household	247	236
Sprinkling	186	420
Total, Annual Average	458	692
Maximum Day	979	2,354
Peak Hour	2,481	5,170

The 10 metered communities are presumed by the authors of the study to be relatively comparable to the 6 flat rate communities in terms of the other important variables besides price that affect water consumption. The table shows that inside consumption is nearly the same in metered areas and flat rate areas. The significant matter is that water consumption for sprinkling purposes is more than twice as much in the flat rate areas as in the metered areas. Also maximum day consumption in flat rate areas is nearly 2-1/2 times that of metered areas. This study does indicate that water for yard use is particularly responsive to price. It suggests that we should distinguish carefully between what we can call the inside and outside uses of water, since the latter is particularly responsive to price changes while the former is not.

5.03(c) The Elasticity Concept

The responsiveness of quantity to price changes is generally measured by economists by defining the concept "elasticity of demand" as the percentage change in quantity divided by the percentage change in price. This is shown in the following formula:

$$N \text{ (the coefficient of elasticity)} = \Delta q/_q \div \Delta p/_p$$

Normally the coefficient of elasticity is a negative quantity.

Elasticity is of further interest for its relation to the change which must occur in total receipts as a result of a price change. If the coefficient of elasticity is less than -1.0; e.g. -1.5 or -2.0, an increase in price will decrease total revenue (p x q) because the percentage change in quantity is greater than the percentage change in price. The coefficient of elasticity for water is believed by economists to be in the range $-1 < N < 0$ for prices generally charged by water suppliers in the United States, but not zero, the coefficient assumed by those who believe that a price change will not alter water consumption. Water price increases then will bring an increase in revenue as well as some reduction in consumption as long as $-1 < N < 0$.

5.03(d) Econometric Studies

Econometrics involves the use of statistical theory and techniques to try to quantify and test economic theories and to utilize them for the purpose of making predictions.

By the use of factor analysis (sometimes called principal component analysis), a statistical technique, the importance of the host of factors which could be associated with variations in an item such as urban water use can be examined. This technique is an attempt to eliminate the redundancies existing among a large number of variables and to isolate a few key variables. For example, by this technique one may establish that to use both income and value of home as determinants of water consumption may in some situations be redundant, since they are so interlocked. On the other hand, price of water involves no redundancy with either item and may be taken with either of them as a major determinant of urban water consumption. Furthermore, an attempt can be made by such analysis to estimate what percentage in the variation in water consumption can be explained by a selected group of variables. Income, for example, seems to be the most significant variable in water consumption, and may possibly account for as much as 40 percent of all variation in consumption in most communities. The significant variables in addition to income (sometimes value of home is used) appear to be price, rainfall and evapotranspiration. Through regression analysis, an attempt can be made to establish a relationship between these significant variables in the form of an equation.

The principal econometric work on urban water demand has been done at Johns Hopkins University by the Residential Water Use Research Project (1962-66) under contract with the Federal Housing Administration. This work has been designed to provide better methods for forecasting water demands than that used by the Federal Housing Administration of simply estimating population and multiplying by an average daily per capita use figure. The major findings reported in their publications (24) are:

1. Inside demands are relatively inelastic with respect to price.

2. Sprinkling demands are more elastic with respect to price in the east, but less so in the west.

3. Maximum day sprinkling demands, so important to system design, are inelastic in the west, but relatively elastic in the east.

One of the project's publications states "Prices can be used as a management tool not only in adjusting revenues but in increasing and decreasing average and maximum day demands".

Beside Howe and Linaweaver's work for the Residential Water Use Research Project, other investigations have studied the elasticity of demand for urban water. These results are summarized in Table V-1.

The coefficients range from -1.09 to -0.02 further illustrating not only the statistical limitations of the attempted applications of rigor to social phenomena, but doubtless also reflecting the distressing absence of fixed functional relationships in economic life. Demand functions, even if they could be known, would also be

Date	Area	Investigator	Price Elasticity
1967	35 United States Study Areas	Howe and Linaweaver	Inside -0.23 Outside -0.93 Average -0.40
1958	34 American Cities	Fourt	-0.39
1958	36 Water Service Systems	Renshaw	-0.45
1969	19 Massachusetts Towns	Turnowsky	-0.65 to -0.40
1964	43 Northern Utah Water Systems	Gardner and Schick	-0.77
1963	Kansas	Gottlieb	-0.66 to -1.24
1970	Chicago	Wong	-0.22
1970	Chicago Suburban	Wong	-0.28
1963	San Francisco Oakland Area	Bain	-1.09

TABLE V–1

SUMMARY OF ELASTICITY OF DEMAND FOR URBAN WATER

continually changing unlike the stable functional relationships of our physical world.

The range of coefficients can be explained, however, to some extent. The N=-0.02 is for the city of Chicago where water use is chiefly inside and where users are not responsive to price, since their water bills are generally paid by landlords. The amazingly high -1.09 is for the San Francisco Bay area where large outside water use and direct payment of water bills by users is common.

In any case it seems established that there is some relationship between price and water consumption other than N = 0 as popularly assumed.

5.04 THE PRESENT AND FUTURE LAS VEGAS WATER CONSUMPTION

5.04(a) The Producers and the Users

The total amount of water produced from all sources in Las Vegas Valley in 1968 was approximately 128,000 ac ft (8) including reclaimed water. The Las Vegas Valley Water District distributed nearly one half of this amount with the remainder being distributed and/or produced by private systems, Basic Management Inc., North Las Vegas, Henderson, domestic wells (total), Boulder City, Nellis Air Force Base and the National Park Service in order of decreasing quantity. The Las Vegas Valley Water District is by far the largest water distributing agency. Table V-2 provides figures from 1959 to 1969 for the sales by this purveyor. It can readily be seen that sales have increased continuously but with marked variation in the annual percentage increase. The relative importance of different water consuming groups is shown in Table V-3. Households, which consume 68 percent of the total water used, are the largest consumers of water.

Per capita use of water in Las Vegas in impressive. It has been estimated at 475 gallons per capita (permanent population) per day. This is a very high figure relative to other cities.

Year	Consumption (1,000 gals.)	Percent Increase During Year
1959	6,865,177	
		10.2
1960	7,562,055	
		8.4
1961	8,200,073	
		22.1
1962	10,010,791	
		14.8
1963	11,492,068	
		19.0
1964	13,670,037	
		4.1
1965	14,230,599	
		9.2
1966	15,546,739	
		4.1
1967	16,182,865	
		10.9
1968	17,906,545	
		4.6
1969	18,725,896	

TABLE V–2

WATER SALES OF LAS VEGAS VALLEY WATER DISTRICT

5.04(a)1 Water Use, Affluence, and Las Vegas. Two

TABLE V–3

DISTRIBUTION OF WATER SALES

Classification	Las Vegas Valley Water District* 1969
Residential	
R-1 Single Unit	55%
R-2 Duplex	3%
R-3 Apt. House	10%
Total Residental	68%
Commercial-Hotels, Retailing, etc.	20%
Industrial	4%
Government	7%
Agricultural	--
Other	1%
TOTAL	100%

*Derived from Las Vegas Valley Water District Revenue Analysis

principal factors work for high water use per capita in Metropolitan Las Vegas, high income levels, and climate. A high proportion of the community lives in single unit dwellings which involve outside as well as inside uses of water. With high income levels, outside uses can be indulged particularly in connection with yards which are maintained despite the absence of rainfall and the presence of high evaportranspiration. This is further made possible by a level of water rates which are quite similar to those found in the rest of the United States, although southern Nevada is one of the most arid areas of the country.

Las Vegas water consumption of approximately 475 gallons per capita per day should not be thought to be high principally because of the climate for it is high when compared to other cities in the west which are similarly arid as shown below.

City	1968 Water Consumption (gpcd)	1968 Rainfall (Inches)	1969 Water Consumption (gpcd)	1969 Rainfall (Inches)
El Paso	170	12.0	176	4.3
Tucson	183	18.1	193	8.8
Salt Lake City	204	21.1	198	16.1
Denver	209	15.0	203	39.0
Phoenix	215	9.4	215	7.2

The explanation for the much higher level of water consumption in Las Vegas in contrast to El Paso and Tucson appears to lie in two related factors. The latter cities seem to give much less emphasis to conventional green lawns than most American cities. This in part reflects the fact that income levels are higher in Las Vegas and therefore people are more likely to live in residences on larger size lots than in El Paso and Tucson where there are a larger proportion of low income families. But even in areas of higher income levels, Tucson and El Paso appear to utilize patterns of landscape architecture that are less water using.

Las Vegas has a sizeable transient population that consumes water, but is not included in the denominator when the number of gallons per capita per day is computed. However a review of water used in other cities in the business and commercial categories indicates that water used by the transient population plus other commercial and industrial uses in Las Vegas is within 1 percent of the national average water use for these purposes.

According to recent statistical studies applying factor analysis and regression analysis, income levels are one of the most important factors accounting for differences in water consumption between cities. Upon this basis some statistical studies project rising levels of per capita water consumption over future years as income levels rise and low income cities move to the water consumption patterns now enjoyed by only presumably wealthier cities. Las Vegas water consumption is predicted to rise in the future, not only because of the expansion of population, but also because of the increase in per capita water use that rising incomes may generate through still larger lots and more irrigated areas, as well as increased numbers of swimming pools and water-using appliances. If the water deficiency forecast for the year 2020 is not to become even larger, it may be necessary to try to find means to induce patterns of life that are less water using than those currently projected for high income groups.

5.04(b) Experience with Rate Increases Relative to Consumption in Metropolitan Las Vegas

The number of price changes in the Las Vegas Metropolitan subarea is not sufficient to provide data for an analysis by statistical techniques. In North Las Vegas the price of water increased in 1966 and 1968.

These price increases are difficult to evaluate as a percentage increase, since they affected the price to users differently by virtue of changing not only the unit price, but also the consumption blocks for these unit prices. The 1968 increases actually lowered the price to very large users.

Assuming that other things remained constant, the 1966 increase of approximately 30 percent was associated with a decline in quantity used of 8.5 percent giving a coefficient of elasticity of -0.28. The 1968 price increase of approximately 17 percent was associated with a decline in quantity of 7.6 percent for a coefficient of elasticity of -0.45.

An average for the two of -0.37 is still modestly encouraging when it is also noted that North Las Vegas is somewhat less oriented toward large yards than are Las Vegas and Boulder City. These coefficients are most likely an understatement of elasticity since the normal tendency for per capita consumption to increase has not been considered.

On February 1, 1968, Las Vegas increased its water rates about 18 percent raising the base payment from $3.25 to $3.85 and the rate per 1,000 gallons from $0.16 to $0.19. Water consumption for 1967 was 38,519 gallons per active account per month and rose to 40,468 in 1968; an increase of 5.1 percent despite the price increase. In 1969 water consumption per active account, with the same prices in effect, fell to 39,066, a decrease of 3.5 percent.

As mentioned before, many factors influence consumption beside price, doubtless these other factors did not remain constant. For instance, increases in rainfall and decreases in evapotranspiration are likely to produce decreases in water consumption per connection. The rainfall in 1968 was a remarkably low 1.11 inches and undoubtedly influenced water consumption in that year. Rainfall in 1967 and 1969 was above normal. Almost all the other factors centering around rising income, such as more water-using appliances, larger homes with more bathrooms, swimming pools, and larger yards, all work to increase consumption per connection.

The coefficient of elasticity in this case would be +0.28 if based on 1968 and -0.19 if based on 1969. The latter gives the normally expected relation; that an increase in price will produce a decrease in quantity. As mentioned before historical experience is difficult to evaluate, cross section studies show more promise.

5.04(c) Comparable Communities

The econometric study of greatest relevance to Metropolitan Las Vegas is a cross section study of 43 water systems in six counties of northern Utah (25). The study includes such large cities as Salt Lake City and Ogden as well as small communities of at least 1,000 people.

Per capita consumption of water varied from 78 to 4,112 gallons per capita per day. The latter level of consumption occurred in a community with an average lot size of 13,557 square feet per capita. In the community with the small consumption, the lot size was only 1,192 square feet per capita.

Other variables considered were as follows with the highest and lowest values found among the 43 water systems.

Variable	High	Low
Price of Water per 1,000 gallons	$ .477	$ .013
Median Income per capita	$1,877	$1.084
Median Value of Homes per capita	$5,000	$2,529
% of Homes having Complete Plumbing Unit	100	74
May-October Average Precipitation per Month, inches	1.18	.65
May-October Average Maximum Temperature, °F	82.8	77.2

This study is of particular value, since it involves consumption of water under conditions of considerable variation in price.

A linear logarithmic equation was fitted to the data, to obtain the demand function shown in Figure V-2. This curve is here presented on arithmetic scales. It has a price elasticity of -0.77 for all points.

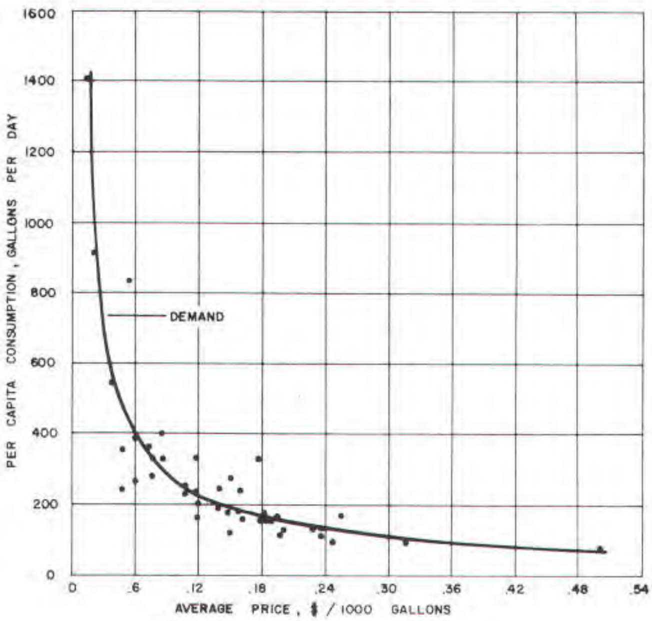
The conclusion of the report is that:

> Price and lot size prove to be the two most important factors effecting variations in the household water use among communities in the test area. Any analysis of projected water requirements for the household sector of Utah's economy must carefully consider the impact of changes in these two crucial factors. Either or both can be altered by public policy decisions. The level of prices and the types of pricing systems are subject to manipulations. Lot size might be affected by zoning regulations and property taxes. Water allocations among communities might well be shifted by public decisions in these two spheres of action.

5.04(d) Water Economy Projections for Las Vegas

It is relatively easy to say that Las Vegas Metropolitan subarea could exist on 39 percent to 28 percent less water per capita in 2020 than it is using now. However, it is far

ECONOMIZATION OF WATER



(FIG. V-2)

DEMAND CURVE OF CONSTANT ELASTICITY FOR HOUSEHOLD WATER IN NORTHERN UTAH 1962

more difficult to predict from what segment of the economy these economizations would come. It is believed that increased water rates would result in variable reductions in use by the various categories of water users. The variable reductions would occur for the following reasons.

1. Rural and suburban residential water use would be moderately reduced through a reduction in area of yard planted.

2. Low density residential water use would be substantially reduced through a reduction in the proportion of people living there, a sizeable reduction in area of yard planted and selection of plants which require less water.

3. Medium and high density residential water use would be increased because proportionally more people would live in this type of housing.

4. Hotel, casino, and motel water use would be reduced only a moderate amount since their ability to pay is relatively high and the cost of water represents only a small part of their operating costs.

5. Agricultural water use would be reduced a substantial amount because it would have a low ability to pay the higher rates and it is one of the lowest benefit uses of water as measured by value of product produced.

6. Highway oriented commercial and industrial water uses would be reduced only a moderate amount since these users generally have an ability to pay the higher water costs.

7. Military and airport uses would be in the same position as would be the industrial uses.

8. Park uses would have to be sharply curtailed by official action. Recognition would have to be made of the fact that Las Vegas will be a water deficient area by 2020 and parks are luxuries, not necessities.

9. School uses would be only moderately reduced since economization would be difficult and the total use small in any event.

Table V-4 is an estimate of how water is being consumed today in Las Vegas Valley. Also, it shows the Boyle-CH_2M (8) projection of where it will be used in the year 2000. In an effort to estimate where it might be used in the year 2020, extrapolations have been made beyond the year 2000 using the Boyle-CH_2M figures for 2000 as a base. The extrapolated figures indicate a possible distribution of water consumption if no reductions of water use were to be effected and indicate possible water consumption in the year 2020 if economization of water were to be effected through judicious pricing policies.

5.05 LONG RUN EFFECTS OF REDUCED WATER USE

5.05(a) Households

The chief impact of water economization would fall upon households. High water rates would presumably cause consumers to change their gardening methods. Sprinkling systems would be designed to minimize evaporation. Plants and shrubs grown would tend more to be those that required less water. Just as artificial flowers have been accepted in the house, chiefly because of cost considerations, so artificial turf and shrubs might come to be accepted in the garden. In the case of homes on large lots using professional gardening services, rising labor costs might also accelerate this development.

From the standpoint of the naturalists and the ecology of the area few things could be more contrary and unnatural than encountering lush gardens and large expanses of green grass in the middle of the desert. Recognition of the aridity of the area might cause the adoption of the desert style dwelling where the cultivated, watered area is limited

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TABLE V-4

GROSS WATER DEMAND FORCAST AND POSSIBLE ECONOMIES

Land Use		Water Consumption Forecast* MGD		Low Population Projection Water Consumption		High Population Projection Water Consumption	
		1970	2000**	Without Economization 2020 MGD	With Economization 2020 MGD	Without Economization 2020 MGD	With Economization 2020 MGD
Rural		5.1	15.4	20.9	14.9	24.5	17.5
Suburban Residential		4.8	19.6	26.6	16.6	31.2	16.2
Low Density Residential		46.6	156.9	213.0	124.2	250.0	90.5
Medium Density Residential		4.7	20.6	28.0	43.0	32.8	53.9
High Density Residential		12.9	24.2	32.9	32.9	38.6	38.6
High Rise Hotel-Casino Motel-Hotel		12.1	25.9	35.2	31.7	41.3	37.2
Agriculture		5.2	25.4	34.5	14.5	40.5	10.5
Highway Oriented		5.0	10.9	14.8	13.3	17.5	15.6
Light Industrial		6.7	30.4	41.4	37.3	48.4	40.4
General Industrial		14.5	48.1	65.3	52.3	76.6	62.6
Military and Airport		1.7	6.4	8.7	7.6	10.2	9.2
Parks		5.0	49.8	67.5	33.5	79.3	29.3
College, University, Schools		0.7	1.7	2.3	2.1	2.7	2.4
TOTALS	MGD	125.0	435.3	590.1	423.9	693.4	423.9
	Ac. Ft. /Yr.	140,000	487,000	660,000	473,000	774,000	473,000
PERCENT REDUCTION				28%		39%	

*These figures assume that no major power generating stations will be constructed in the Las Vegas Metropolitan subarea.
**Boyle-CH_2M report, Table 14.3 (8).

to an inside courtyard, rather than a large cultivated lawn around the home.

Single dwelling lot sizes would tend to become smaller and more multiple unit dwellings would arise, economizing on gardens and swimming pools. This movement toward smaller lot sizes and multiple dwelling units might be further reinforced by zoning measures and controls exercised over the extension of water lines to new subdivisions. Presumably such drastic measures would be chiefly the product of a decision to limit urban sprawl, reduce smog by reducing commuting distance, and economize on public utility extensions to new areas, rather than simply a movement to economize on water. In any case water economy need not result in the communities becoming less attractive if imagination and adaptiveness are shown. Greenery is not the only dimension of beauty, and even greenery can be maintained through better water use or the use of artificial turf, shrubs, and even trees. Those valuing highly the natural flora could obtain it. The presumption, however, is that most people would seek to secure beauty through cheaper means.

5.05(b) Industry

The base industry complex of metropolitan Las Vegas, casinos, hotels, and motels, are low water users relative to the value of the services produced. When the cost of water is compared with the revenue per visitor, tourism appears as a very low water using base industry compared to paper mills, foundries, etc. Thus even higher water rates probably would not adversely affect the location of more casino-hotel-motel enterprises in Las Vegas. Casinos, hotels and motels, like other consumers, might at a higher price, practice somewhat more water economies, but these would in no way affect adversely the growth of the city.

5.05(c) Government

Local governments could effect substantial water economies through directives to park managers and others relative to the use of water. The Federal Government is also a large user of water and could be requested to review its water uses. Again it hardly appears that water economization would have any adverse effects upon the activities of either local or national governmental units.

5.06 THE ECONOMICS OF WATER PRICING

5.06(a) Traditional View

Water has generally been priced in American communities so as to cover its average cost of production. Furthermore, it has been considered a decreasing cost industry, since once a water distribution system is built, larger volumes of water can be delivered at lower and lower unit prices. Thus it has been customary through block pricing to offer lower water prices to big users.

The price of water has almost never reflected any basic scarcity value of water per se, since in most areas water is abundant as either renewable surface or ground water. It is scarce only in that delivery at the point desired and in the form desired involves storage, pumping, aqueducts, purification and other transmission and distribution costs; almost all of which as mentioned before involve decreasing cost per unit with increased output.

Water has not been regarded like oil whose scarcity value, quite apart from delivery cost, is recognized. In Nevada, unlike most other states, water is an extremely scarce resource. The intrastate projects proposed here involve the mining of scarce deposits of water which in truth are very valuable, because any substitutes for them would have to be brought long distances by aqueducts from other states at very high costs.

5.06(b) Suggested View

Water then in fact is not a truly continuously decreasing cost item. As more water is needed, higher and higher costs must be entailed to bring it longer and longer distances and scarce limited supplies are mined. It is only proper to put a price on these non-renewable supplies to reflect their value to water users and to assure their economization. Thus water in southern Nevada may be considered currently underpriced. Price at the very least should be equal, and eventually must equal, the cost of obtaining it from the next supply source.

5.07 STRATEGY OF WATER RATE INCREASES

If it should be decided to raise water rates so as to reflect the relative scarcity and costliness of water in the area, the matter of timing the increases and obtaining public support for them should be considered in advance.

5.07(a) Timing

If the objective of setting an increased price for water is to promote the economization of water, there is much to be said for a substantial increase at once, rather than a series of small increases over several years. A dramatic increase in rates will cause people to review their present uses of water with thoughts of economy in mind. It is important that the increase be sufficient to alter the price of water relative to other things, rather than that the increase appear as simply another aspect of the general slippage of the price level upward. The present time would be a most opportune moment for a rate increase in that the advent of water from the Southern Nevada Water Project does involve higher costs that must be passed on, at least to some extent. The price increase might, however, reflect fully the higher cost of water beyond present immediate supplies so as to bring about a pattern of water use fully reflecting the ultimate scarcity and high cost of water in the area.

5.07(b) Educational Campaign

The public should be fully informed of the reasons for the price increase. Emphasis should be placed on the fact that people will have full liberty to use as much water as they wish, but that only through economization can water bills be maintained at old levels. It should be pointed out that the objective is not to dry up yards, but to get people to use water more effectively by stopping waste, using more effective sprinkling systems, and designing yard and landscape plans that will economize on water use. Informational literature and talks should be utilized. The advice and services of the local offices of the United States Department of Agriculture should be sought in this connection.

5.07(c) Reasons for a Higher Price for Water

Much would be gained by a higher price for water.

1. The relative scarcity of water in the Nevada desert area would be recognized with the result that water would be economized in many different ways.

2. Costs of elaborate and expensive aqueduct systems such as those in this report might be avoided. Even if they were only postponed, a saving would result.

3. The position of the State of Nevada would be strengthened in dealing with other states in that the scarcity of water in the state would be fully reflected by its price. At a higher price, water supply projects from outside the state might appear economically feasible.

4. A higher price for water would provide additional revenue for financing future water systems or could be used to meet the rising costs of local government.

5. A higher price for water would not only encourage individual economy, but also system economy as well. If

a more realistic price for water is set, more activity in stopping water leakage would be justified economically.

6. The seasonal peaking problem, which results in water consumption three times as high in summer months as in winter months, requires expensive system design to handle such peaks. The peaks are almost wholly caused by outside uses in watering yards. Higher water rates would do much to reduce such peaks and their costliness.

7. A high price would in the long run stimulate a water saving technology which would alleviate the problem. Treatment of available low quality water, water recycling, water economizing devices, etc. -- all only become desirable upon the basis of the savings which can be obtained from their use based on a higher price for water.

5.07(d) Required Price Increase to Reduce Consumption

The elasticity of a demand function may be different at different points. In the relevant range above the current price in the metropolitan Las Vegas area it appears reasonable to believe that the coefficient might be at least -0.3 to -0.4. This is considerably less than indicated by the Northern Utah study of -0.7 which should have some relevance to the southern Nevada situation. However, based on the experience with the two price changes in North Las Vegas and the one price change by the Las Vegas Valley Water District, caution in estimating too high an elasticity coefficient may be in order.

To accomplish a reduction in consumption of from 28 to 39 percent, the following price increases would be required:

	Increase in Price of Water for a Decrease in Quantity Consumed of:	
N	28%	39%
-0.3	+94%	+130%
-0.4	+71%	+98%

These increases are substantial. They might be labeled unreasonable in which case they would probably accomplish their objective - reduced water consumption.

VI PART 2 POPULATION REDISTRIBUTION

POPULATION REDISTRIBUTION

6.01 GENERAL

6.01(a) Basic Concept

Prior sections of this report have explored the possibilities of importing water from subareas of surplus to the Las Vegas Metropolitan subarea. A plan also has been presented for alleviating the predicted water shortage by reducing the consumption of water. A third alternative is to eliminate a water shortage by maintaining a lower population in Las Vegas and by encouraging the growth of communities in subareas outside Las Vegas. Thus the people would live where the water is instead of where it is not.

The stimulation of the growth of new cities through the offering of water in order to produce a population dispersion does not appear encouraging.

Two possible situations exist. In the first, water and space may be offered to attract base industries, which will in turn attract residents. Upon the advent of these base industries, sizeable cities with a complement of local service activities would then arise. Unfortunately, for this simple proposal of population direction through the inducements of water and space, water is seldom an important enough item to attract industries even when it can be made available at very low cost.

The second situation is directly relevant to this study. It involves the bedroom community where people work in one community such as Las Vegas but have their residence outside it. If people attracted to employment in Las Vegas in the future would settle in surrounding communities that have water, the cost of aqueduct systems studied in this project could be avoided and in the opinion of many, the quality of life would be improved by the resulting population dispersion.

6.01(b) Growth Effects in Large Cities

Increasing city size results in features which make life in a metropolis more costly and also less attractive. Rents rise with concentration of population. Streets and neighborhoods become crowded. Congestion develops. Air pollution becomes critical. Some people then move to the suburbs or possibly relocate their employment to an area with less population. Others decide not to move to the city since employment opportunities no longer outweigh the disadvantages of life there.

Meanwhile, as the city grows the business enterprises of the city are likely to be confronted with higher costs among which are the rising cost of labor based on the demand of workers for more money if they are to continue to live in a situation of rising living costs and deteriorating environment. Thus, growth is restrained by environmental unattractiveness to the individual and by higher costs to business. This process has been already well documented in the case of New York City. It can be seen that market forces do impose restraints upon the ultimate rate of growth of cities. But these forces work slowly and permit cities to become larger than many people think desirable. Currently, many economists feel that the market system fails to check city growth sufficiently because not all the costs of urban concentration are presented directly to individuals and business firms. Thus, a firm may build a plant in a metropolitan center which it would not build if it were required to pay directly a million dollars a year for the full elimination of the smog and congestion it causes. Similarly, a worker may choose to live and drive a car in the city because he does not directly pay the full cost of the freeway system he uses, the congestion he causes, and the contribution which he makes to smog. If presented with a daily bill of 50 cents a mile for car use in the central city, he might well choose to use public transportation or choose to live and work elsewhere.

Even if people did pay directly and fully all costs of urban life this still might not limit cities to what many people feel to be a desirable size in terms of the quality of human life. Thus, in addition to the economic costs of city life, there are certain intangible social costs that should be added. It is argued that with the growth of large cities there arises within them a loss of the sense of community which gives individuals a sense of responsibility and belonging. Individual anonymity, social tensions and crime mount.

6.01(c) Advantages of Dispersing Population

POPULATION REDISTRIBUTION

One of the most unhealthy aspects of population growth in the United States has been the trend toward increasingly greater population concentrations in and immediately around large urban centers. The result of this trend, the American megalopolis, poses a threat to the social, environmental, and economic welfare of its citizens. Air pollution, ghetto conditions and exorbitant rent are just a few of the unhealthy consequences of living in and around a megalopolis. Hence, a program of dispersing population away from the Las Vegas Metropolitan Area would be beneficial because it would avert some of these situations.

In addition to reducing the possibility of severe environmental pollution, ghetto conditions, and high rent prices, many other environmental, social and economic advantages would be realized by a dispersed rather than a centralized population distribution. For example, traffic conditions would be less crowded, land costs and other costs related to home construction would be less due to mass construction, and water could be supplied more cheaply because development would take place in areas close to the available water supplies. Also, the movement of population growth from the Las Vegas area would postpone the obsolescence of public facilities in Las Vegas while at the same time providing for the opportunity of planning new communities to insure orderly growth in the areas of dispersed population. The opportunities for growth and development in the outlying areas would be preserved because the natural water resource would be retained for use in the individual areas.

Hence, the dispersion of population away from urban centers most surely would result in improved living conditions. However, there are problems related to dispersion. Some will argue that the large megalopolis provides cultural and entertainment opportunities which would not be found in smaller or more dispersed population centers. In addition to this argument, there is the problem of effecting a dispersion of population.

6.01(d) Disadvantages of Dispersing Population

The fact remains that despite high congestion, pollution, and crime, living in central cities is attractive to many.

1. Large cities for many people offer a more interesting life. A wide range of services is available--professional sports, educational facilities, and medical centers also contribute to the much discussed quality of life.

2. Large cities offer a wider economic base and greater economic opportunity.

3. Public services--libraries, museums, etc. are more highly developed in large cities.

4. Dispersion to smaller towns involves increased commuting costs and loss of time. High speed transit to suburbs could reduce time required, but it raises transportation costs. In any case, some loss of time remains.

6.01(e) Difficulties in Dispersing Population

The basic objection to the proposal to bring the people to the water is that the people cannot be directed by some governmental authority to come to the water. The American society is one based on personal freedom and among the most highly valued freedoms is freedom of choice in matters of employment and place of residence. People can only be offered inducements to come to certain areas and to take certain jobs. Through planning, inducements may be altered, but no assurance can be given that the inducements or detractions that a planning authority can utilize will achieve what it considers to be desirable goals.

It is true that people in a state such as Nevada can be kept from settling and developing an area if water rights are denied them. The great importance of water in Nevada, however, may have given the illusion that more can be accomplished through water planning than is the case. The mere granting of water rights, for instance, does not assure settlement and development if there is no viable economic base for such settlement.

More important to water planning is the case of existing cities with existing water supplies. What is considered undesirable further growth for such cities cannot be simply halted by water planning. As noted earlier in this report, the per capita water needs of a city are not a fixed amount. Once alloted, a given quantity of water can be economized so as to support a larger population. Declining per capita water supplies along with declining amounts of pure air and space will make cities less attractive and will certainly dampen metropolitan growth. How great would be the dampening will depend not chiefly upon water but upon how great the financial inducements pulling people to the metropolitan area are as compared with the disadvantages.

6.01(f) Means of Dispersing Population

What will lead more people to disperse over southern Nevada in the interest of improving quality of life? The measures required to affect individual choice must obviously be of two types. Discouragement to continuing residence or to locating in Las Vegas, and encouragements to locate in outlying areas. Discouragement as has been seen is furnished by growth itself as it affects the market mechanism. Beyond this the costs of urban life that are neglected at present by the market could be incorporated into the mechanism through the assessment (against individuals and industry) of the full cost of congestion and pollution.

Beyond these measures, residents in cities could be discouraged by the use of taxation, in fact, this already happens in part in that large cities require a disproportionately higher amount of governmental services with resulting higher tax bills.

All these measures mentioned are negative and are likely to engender more opposition than movements to induce people to disperse. Positive incentives toward dispersion would involve subsidies in regard to transportation and housing for those who would move to more distant areas. The subsidies would presumably be justified on the grounds that savings would be furnished people in the metropolitan area by the reduction of congestion and other matters as well as the specific savings of lower water costs.

6.02 NUMBER OF PERSONS INVOLVED

As Las Vegas approaches the year 2000 and a population of about 750,000, a critical point in the dispersion of Las Vegas population will probably be reached. By 2000 substantial portions of Las Vegas that were built in the immediate post-World War II period will be fifty years old or slightly older. Las Vegas growth has been so relatively recent that the city at present is basically a new city. By 2000 it will be approaching middle age with a normal age distribution of its buildings. The loss of newness may lead people to seek such newness or modernness in relatively far-removed new commuter cities.

With a population of 750,000, the present planned areas of land use in the close proximity to Las Vegas will have been filled and the shortage of empty space in the established area will involve high costs of demolishing old buildings for new projects. Higher land values will presumably make dispersion economically attractive. At this time there may be simply a further extension of the metropolitan community to nearby areas or there may be a sizeable jump to more distant areas such as those of this study. Movement to more distant communities in preference to areas closer at hand may be based on the higher land values of the Las Vegas fringe areas. Also an important attraction may be the availability of water in the more distant areas.

Dispersion can be conceived as beginning as early as 2000, and accounting thereafter for a large part of the growth of southern Nevada in the period from 2000 to 2020. The size of dispersion, if it occurs, might vary in accordance with the high and low population projections given in Table VI-1. In addition to showing possible dispersion populations in the various subareas, Table VI-1 also lists the maximum population that each subarea could accomodate with its present water resources. It is interesting to note that population dispersions will involve more people by 2020 than live in Clark County at the present time.

There are six areas to which population might disperse. One of them, Railroad Valley, has at present only minimal agricultural activity. The remaining five areas, Moapa Valley, Virgin Valley, Pahrump Valley, Amargosa Desert, and Pahranagat Valley, all have populations less than 2,200 but have moderate agricultural activity plus at least roadside retail activity.

Estimates of the dispersed population and its distribution have been made on the basis of the following assumptions:

1. Dispersion will be a public policy promoted and aided financially by some level of government.

2. Large real estate firms or governmental agencies will in some situations promote the building of communities and make residence there attractive. These large community projects, possibly in Pahrump Valley and the Amargosa Desert would only be undertaken where large water supplies are available. Because of lack of large quantities of water or because of low quality water that would involve considerable treatment costs, the Moapa Valley and Virgin Valley would probably be among the last areas to be developed on a large scale.

3. Within the framework of what government and private industry may offer commuters in terms of housing and transportation, consumer preferences will determine where people will live. The chief factors influencing people's choices will be:

   a. The distance of the community from Las Vegas. Communities nearby will generally be more preferred than those substantially further away. Thus even without the aid of large projects, the Moapa Valley subarea will grow, since it is close to Las Vegas.

   b. The types of rapid transportation available will be important. Again, although likely never to have a large-scale promoter, the Moapa Valley will be attractive because of the existence of an interstate highway. Promoters of other areas will probably also have to promote transportation facilities between these areas and Las Vegas.

   c. The present physical attractiveness of a community will be important to the choice made by people of where to live.

TABLE VI–1

POPULATION PROJECTIONS WITH SIZEABLE DISPERSION OUTSIDE LAS VEGAS

Area	1970 Est. Pop.	1980 Low	1980 High	2000 Low	2000 High	2020 Low	2020 High	Estimated Maximum Population Based on Local Water Resources
Projected Metropolitan Las Vegas	265,000	300,000	500,000	610,000	1,000,000	1,100,000	1,300,000	850,000
Projected Dispersion From Las Vegas	-	-	25,000	100,000	300,000	300,000	450,000	-
Resulting Las Vegas Population	265,000	300,000	475,000	510,000	700,000	800,000	850,000	-
Fort Mojave	50	100	20,000	5,000	40,000	40,000	60,000	60,000
Moapa Valley	2,200	4,000	20,000	20,000	35,000	30,000	50,000	50,000
Virgin Valley	1,100	2,000	4,000	5,000	7,000	8,000	10,000	10,000
Pahrump Valley	1,200	2,000	40,000	73,900	305,000	214,000	400,000	500,000
Amargosa Desert	1,500	1,500	4,000	7,000	50,000	20,000	100,000	320,000
Railroad Valley	100	100	200	100	200	100	200	660,000
Pahranagat	300	300	5,000	8,000	45,000	20,000	70,000	300,000

NOTE: Figures for individual small community highs when totaled will exceed total population figure given for small communities since the total could be distributed in many different ways among the communities.

6.03 POTENTIAL OF SUBAREAS FOR RECEIVING INCREASED POPULATION

6.03(a) Fort Mojave

The Fort Mojave subarea is located about 100 miles south of Las Vegas at the southerly tip of the state. Its easterly boundary is the Colorado River. The closest cities are Bullhead City, Arizona (10 miles); Kingman, Arizona (39 miles); and Needles, California (16 miles). Davis Dam across the Colorado River is just north of Bullhead City.

To date the only development in Fort Mojave is the construction of the Southern California Edison Company steam generating plant. This 1,500-MW plant will be operational in the near future.

The Colorado River Commission has purchased or plans to purchase from the United States about 15,000 acres of land in the area and has had a master plan of development prepared. Conditional sales agreements have been made with four development firms to improve most of the land. Included in the plans to date are residential sites for second homes and retirement homes. In addition to the usual commercial enterprises, plans have been made for casinos and hotels. Golf courses, marinas, recreational facilities, and an airport are planned.

The Colorado River Commission's allotment of 13,000 acre feet of Colorado River water for these four developments will supply enough water to satisfy the demands of an equivalent population of about 60,000 people at the rate of 200 gpcd. Additional water supplies may be available from the ground-water basin, but that source needs more study before any definite values can be assigned to it.

6.03(b) Moapa Valley

Situated about 55 miles northeast of Las Vegas, the Moapa Valley is composed of four farming communities and acts as a tourist center and home of a Nevada Power Company steam generating station. This subarea is cut in two parts by Interstate 15 which provides excellent highway transportation between the subarea and Las Vegas.

The economic potential of the area would appear to lie in the development of tourism and recreational activities as a base industry and development of a suburban residence community for Las Vegas workers by the diversion of agricultural land, and its water rights, into residential subdivisions. The tourist attractions, Lake Mead, the Valley of Fire and the Lost City Museum, are already visited by commerical tours from Las Vegas. Immediate further development of camp sites, trailer parks, and recreational areas appears likely. Beyond such development in the future might be that of resort hotels.

Prospects of a bedroom community appear good. The Moapa Valley is one of the areas to which people desiring to live outside of the Metropolitan area of Las Vegas might be most likely to turn. It is within an hour's drive on a four lane transcontinental highway. The area is green in contrast to the surrounding desert and presents a very attractive appearance with trees and highly productive agricultural fields. Its recreational facilities further add to its attractiveness.

The Moapa Valley receives about 34,000 acre feet of water a year from the flow of the Muddy River which is fed by 21 springs in the upper valley. This water is presently used for irrigation, domestic purposes, cooling at the steam generating plant, and other industrial purposes. Beside the surface water, there is about 800,000 acre feet of poor quality ground water in the upper 100 feet of saturated valley fill, however, only the springs have been considered a source of water for future development.

With greater congestion and attendant problems in Metropolitan Las Vegas, a likely movement to this area can be envisioned. People, desiring a semi-rural mode of life, would first buy parts of existing farms. Later, real estate firms noting this movement might buy larger farms and subdivide them using existing water rights to support an enlargement to the local water distribution system for their subdivisions. On the basis of the 34,000 acre feet of water from the springs being made available for residential and industrial purposes, expansion to a population of 50,000 could occur without creating a problem in the local water supply. Peaking storage would have to be constructed in order to meet the high summer demands.

6.03(c) Virgin Valley

The Virgin Valley (population 1,100) is northeast of Las Vegas. It contains the towns of Mesquite and Bunkerville which are about 80 miles from Las Vegas along Interstate 15. Agriculture is the base industry of the area with 3,000 acres presently in cultivation. Dairy and beef cattle also are raised locally. Mesquite does a substantial business with travelers passing through the center of town on U.S. Highway 91.

The economic potential of the Virgin Valley would appear to lie chiefly in further development of road side tourist activities and also in its possible development as a bedroom community for Las Vegas.

As either the first or last Nevada community offering gaming activities along Interstate 15, stimulation of casino activities can be envisioned. The next cities along Interstate 15 are Las Vegas (80 miles to the west) and St. George, Utah (52 miles to the east). These separations contribute to the importance of Mesquite as a stopping point.

While the 80-mile distance to Las Vegas makes the Virgin Valley less attractive as a living place for people working in Las Vegas than the 50 to 60-mile distant places such as Moapa and Pahrump Valleys, the existence of an interstate highway all the way to Las Vegas means that travel time can be held to less than an hour and a half. This time is not prohibitive for today's commuters. Mesquite and Bunkerville, particularly the latter, also offer attractions as old established communities along with the physical attractiveness of the green valley area.

The Virgin Valley has an abundance of water, but unfortunately most of it is of poor quality and the surface flows are erratic. It is not known how much water could be economically extracted from the ground-water basin. For the purposes of this report, it has been assumed that about 5,000 acre feet per year could be withdrawn. This amount would be sufficient to supply the domestic demands of about 10,000 people. A water supply for additional population could be achieved by acquiring water rights in the Virgin River and storing, diverting and treating river flow, all of which would be expensive. It may be possible to more fully develop the ground-water basin without having to treat the water extracted.

6.03(d) Pahrump Valley

Pahrump Valley is westerly of Las Vegas and on the west side of the Spring Mountains. The commercial center of the valley is 60 miles from Las Vegas via a two-lane road. The base industry is agriculture, but a strong push has started in recent years to make an urban area of the valley.

The economic potential of the valley would appear to lie in one or both of two directions. Its proximity to Las Vegas would make it conceivable to be developed as a bedroom community. A start has already been made in this direction.

The second possible economic potential is that of tourist-casino type development. Unfortunately for this type of business Pahrump is not on a transcontinental highway. Tourist-casino businesses have been attempted in other remote areas in Nevada with only moderate success. They haven't been able to create a base industry that would support an appreciable population in these remote areas.

Thus it would appear that the greatest potential for Pahrump Valley would be to develop as a residential community providing housing for workers from the Nevada test site and Las Vegas. Some hotels and casinos may be able to flourish with the support of local residents and "package tours" flown into the valley.

The perennial yield of the ground water basin (12,000 acre feet per year) would only support a population of about 27,000 if the water consumption averages 400 gpcd and if agriculture is curtailed.

Mining of ground water would allow a much larger population to exist in the valley. Assuming that 4,200,000 acre feet are recoverable from the top 100 feet of the basin and the perennial yield is available, an average population of 500,000 could be supplied with ground water at the rate of 400 gpcd for a period of 20 years. A supplemental supply would have to be brought to Pahrump after that much ground water had been extracted.

6.03(e) Amargosa Desert

Located about 125 miles northwest of Las Vegas and between U.S. Highway 95 and the California border is the Amargosa Desert. The town of Beatty (population about 1,200) is at the north end of the desert. At the southeast tip is Lathrop Wells (population about 100). The pleasure resort of Ash Meadows is situated at the south edge of the desert near the California state line. The base industries are tourism and agriculture.

Its distance from Las Vegas probably will preclude Amargosa Desert from becoming a bedroom community. Tourism appears to be a source of economic potential to the subarea because of its location near Death Valley National Monument and along U.S. Highway 95.

The agricultural potential recently was investigated by the U.S. Bureau of Reclamation. The USBR concluded that an expansion of agricultural activity is feasible and would be beneficial to the subarea contingent upon the mining of ground water in the basin.

In the event large scale population dispersion is effected, the ground-water basin could support a medium size city, although it would require treatment to remove the fluorides. The perennial yield of the basin (24,000 acre feet per year) would be sufficient to supply water to 53,000 people at a rate of 400 gpcd if all agriculture were eliminated.

Ground water mining would provide water for a substantially greater population. Assuming that 2,400,000 acre feet are recoverable from the top 100 feet of the basin and the perennial yield is used, an average population of 320,000 could be supplied with ground water for a period of 20 years at the rate of 400 gpcd. As with the Pahrump Valley ground water basin, a supplemental supply would be required after the extraction of that much water.

6.03(f) Railroad Valley

Railroad Valley is located over 200 miles north of Las Vegas in the sparsely settled central part of the state. There are no sizeable communities within the valley. The base industries are agriculture and oil production. Both are very limited. The potential of the valley appears to be a continuation of today's situation. No large residential communities seem likely. Agricultural development may occur as more farm and range land is required in the future, but there is no movement toward developing additional farm acreage in the valley.

The large water resource stored in the ground water basin is attractive as it far exceeds demand now or in the near future. The perennial yield of the basin has been estimated to be 52,000 acre feet per year and the volume of recoverable storage in the top 100 feet to be 4,900,000 acre feet. The perennial yield alone would support 115,000 persons at a rate of 400 gpcd if there were no agriculture. The ground water in storage plus the perennial yield would be capable of supplying water to a population of 660,000 at a rate of 400 gpcd over a 20-year period. A supplemental supply would have to be obtained in order to continue with a population of that size.

6.03(g) Pahranagat Valley

The beautiful Pahranagat Valley is located about 100 miles northeast of Las Vegas along U.S. Highway 93. It is connected to Las Vegas with a two lane road from a junction with Interstate 15 near Apex, Nevada. The base industry of this subarea is agriculture with some minor tourist activity.

The economic potential of the subarea is believed to lie with a continuation of agriculture and an increase in tourism. The proposed shortening of U.S. Highway 93 between Alamo and Ely coupled with increasing recreational facilities near Caliente should result in greater tourist trade for the roadside business in the valley. The distance from Las Vegas makes the valley a poor area for residential development in which to shelter commuters.

The perennial yield of the ground-water basin (25,000 acre feet per year) would support 55,000 persons using 400 gpcd if all agricultural development were to be stopped. The ground water in storage in the top 100 feet and available for removal amounts to an estimated 2,200,000 acre feet. A population of 300,000 could be supplied with water at the rate of 400 gpcd for a period of 20 years if the perennial yield and that storage were used.

6.04 EFFECT ON LAS VEGAS OF A POPULATION DISPERSION POLICY

The principal impact of a population dispersion policy would be on Las Vegas land values. Traditionally land values are higher in a rapidly expanding area than in a static area. Large scale dispersion would materially slow down the rate of expansion in the Las Vegas Metropolitan subarea with a resultant reduction in land values. This would in part offset the dispersion policy by making Las Vegas a more economically attractive place for non-home owners to live.

Las Vegas municipal government would find itself with the same problem that perlexes other large cities today that have a sizeable commuter population. This commuter population it is felt makes substantial use of metropolitan government services by the fact of its daily presence yet does not pay property taxes and other taxes paid by residents. It may also escape city sales taxes since most of its income may be spent in the commuter suburbs. Payroll taxes levied at the place where the commuter works may be utilized to make the commuter pay what is felt to be his share of urban governmental costs. There still remains the charge that the commuter uses the city, but is not interested in it. Today large cities with commuter populations have often contended that the growth of these populations has contributed to the decay they are experiencing. Interest to date by cities has been chiefly in halting a flight to the suburbs rather than promoting it.

6.05 MASS TRANSPORTATION

Attendant with population dispersion is the problem of transporting great numbers of commuters to and from the Las Vegas Metropolitan subarea. A great many of the people who would be dispersed to the outlying subareas would be employed in the Las Vegas Metropolitan subarea, and these would require a quick, convenient means of travel to their place of work.

The cost of commuting has been estimated for four different modes of travel. These costs have been determined on the basis of the fares paid by the commuters. The following subsections discuss the economic analysis of the mass transportation system needed to accommodate the population dispersion necessary for averting the projected water shortage.

6.05(a) Number of Persons Involved

The number of persons that might be located somewhere outside the Metropolitan Las Vegas subarea has been estimated as high as 450,000 by the year 2020. Of this total perhaps 65,000 would be regular commuters to Las Vegas. On the average, an additional 15,000 people might commute to Las Vegas on an irregular basis and for non work associated activities. The total daily commuting traffic might be as high as 80,000 people. The commuters presumably would be traveling to Las Vegas from several separate remote communities in Pahrump Valley, Moapa Valley, Virgin Valley and Amargosa Desert.

Some of these commuters would insist on driving their own cars while others would be content with mass transportation. For the purposes of this report, it has been assumed that 65,000 commuters would travel each working day between the outlying subareas and Las Vegas on mass transportation. The remainder (say 15,000) would travel by private car; an average of three persons to a car. Also, it has been assumed that the weighted average round trip distance would be 120 miles.

6.05(b) Buses

For short distances, buses are one of the least expensive methods of mass transportation. In the southern Nevada area, fares for bus trips of about 100 miles usually are about 4 cents per mile. Since the distances which would be involved in transporting large volumes of commuters to Las Vegas from outlying areas of dispersed population centers are approximately this distance, a fare of 4 cents per mile has been assumed in this study.

On the basis of a fare of 4 cents per mile, the daily passenger fare to Las Vegas and return would amount to $4.80. Total daily passenger expenditures for 65,000 round trips would be $312,000, which amounts to an annual expenditure of nearly $78,000,000. Not included in this cost estimate is the cost of improving the roads to handle the higher volume of traffic which would occur; presumably this cost would be paid from taxes generated from the operation of the buses.

6.05(c) Freeways and Automobiles

When confronted with short distance trips, most people first think of traveling by automobile. The conveniences associated with automobile travel have resulted in the large volumes of highway traffic which are common today. This form of transportation has an important advantage over other forms of mass transportation in that there is no concern of getting to and from the bus station, airport, or train station. In addition, upon arriving in the city where they work, automobile commuters have the added flexibility of conveniently traveling within the city.

In general, costs associated with owning and operating an automobile are approximately 12 cents per mile or 4 cents per person per mile with an average of three people in each car. The daily cost of 15,000 people traveling 120 miles in cars would be $72,000. The annual cost would be $18,000,000. For 80,000 people to travel 120 miles in cars each day the costs would be $384,000 per day and $96,000,000 per year.

The cost of improving the road system to handle the heavy automobile traffic which would result from commuting by automobile has not been included in this cost estimate. In this case the road improvements would necessarily be much more costly than the improvements required for handling buses because of the much greater traffic volume which would result. Again, however, it has been assumed that taxes on automobile operation would pay for the cost of road improvements and maintenance.

6.05(d) Rail or Monorail

One of the possible modes of high speed transportation which has been investigated in this study is a tracked air cushion vehicle. A recent report by Kidde Constructors, Inc. and TRW Systems Group (26) has been used as the basis for this investigation. The plan proposed in that preliminary report is to provide high speed tracked air cushion vehicle (TACV) service from Los Angeles to Palmdale and thence to Las Vegas.

The unit cost given in that report is 10 cents per mile per person. That figure has been used herein even though it is a projected figure and not based on operating experience.

The cost of moving people a distance of 120 miles each working day would amount to $12.00 per day. For 65,000 daily commuters the cost would be $780,000 per day or $195,000,000 per year.

6.05(e) Air

Economies in air travel are gained from long distance trips, especially when meal and lodging costs are avoided by quick travel to a destination. The use of airplanes in a short distance mass transportation system could result in a rapid system, but the costs involved would be high. Typical air travel costs for 60-120-mile flights have been found to be approximately 17 cents per passenger mile and 13 cents per passenger mile, respectively. These are representative air line costs for short distance trips made at this time. It is possible that a high volume passenger load could result in efficiencies which would enable a slight reduction in fare; however, most probably the magnitude of the reduction would be small. For the following cost analysis, a fare of 14 cents per passenger mile has been used.

As before, it has been assumed that 65,000 commuters per day would travel to Las Vegas and return. The daily round trip fare would then be $16.80 per commuter. Total daily and total annual commuter costs to Las Vegas and return would amount to $1,090,000 and $273,000,000 respectively.

6.05(f) Summary

A summary of the estimated costs for each alternative is given in Table VI-2. It is of note that the annual commuting costs substantially exceed the annual cost of an aqueduct system to bring sufficient water to Las Vegas. Therefore, from an economic standpoint, population dispersion is not feasible.

TABLE VI–2

ESTIMATED COST OF COMMUTING IN YEAR 2020*

Method of Mass Transportation	Mass Transportation (65,000 persons) Daily	Automobile Transportation (15,000 persons) Daily	Total (80,000 persons) Daily	Annual Commuting Cost
Bus	$312,000	$72,000	$384,000	$96,000,000
Automobile	--	--	384,000	96,000,000
Monorail (TAVC)	780,000	72,000	852,000	213,000,000
Airplane	1,090,000	72,000	1,162,000	290,000,000

*Assuming a total of 450,000 people are dispersed.

VII PART 2 LIMITING POPULATION GROWTH

LIMITING POPULATION GROWTH

7.01 GENERAL

One possible solution to the impending water shortage for southern Nevada is to eliminate the need for additional water supplies by reducing the rate of population growth. This alternative solution would necessarily be involved with a program of limiting family size and/or reducing the amount of migration into southern Nevada. Its implementation would most likely be a very difficult and sensitive task. As will be described in the following paragraphs, the public and governmental attitudes on population growth have undergone almost a complete reversal since the early days of the country. Traditional and moral viewpoints that depicted large families as the most desirable and righteous family size have come under attack on both levels in contemporary times. Immigration, which was originally encouraged by the government, was later discouraged. Because the subject of limiting population growth touches upon two fundamental American beliefs, the freedom of choice to determine one's own family size and the freedom to move where one desires, there are many vehement and impassioned arguments against a program of limiting population growth. The role that the government should play in this matter is also open to considerable discussion. The next few paragraphs will give some background on the historical development of the views on controlling population growth.

7.02 HISTORY

In the early days of the country, the common policy with regards to population growth was to encourage large families and immigration. During this period, much of the new country was unsettled and the government desired to promote settlement in order to have claim to more land. The general attitude of the public also was to produce many offspring since there were many benefits realized by the parents of large families. Because the society was mainly rural, large families enabled the farm work to be handled entirely by family members. The urban family also benefited from large size by increased income from jobs held by minor children.

One of the earliest attempts to promote a policy of limiting family size in the U.S. was that of Charles Knowlton in 1832. Knowlton was eventurally fined and imprisoned for committing an offense against public morality. The Comstock laws of 1873 were obstacles to publication of birth control information in that they prohibited obscene literature. In 1916, Margaret Sanger's attempt to open a birth control clinic resulted in court suits between those for and against family planning.

The great early growth of the nation was primarily the result of large scale immigration from European countries. There were hardly any restrictions imposed upon immigration at this time because with immigration more and more of the nation was being settled. Even after most of the land was settled, there was still a need for immigrants to work in the new factories of the industrial revolution which was coming into existence at the time.

Once the land was settled for the most part and the industrial revolution was well under way, the policy of the federal government began to shift from a policy of encouraging immigration to discouraging it. The Chinese Exclusion Act, the Alien Contract Labor Law, and the Quota Laws of 1921 were all intended to slow down immigration from what it had been. In 1965 the quota system was abolished, and, as a result, immigration sharply increased. Under the present policies, it has been estimated that about "70 percent of the net inflow of migrants into metropolitan areas will be foreign immigrants" (27).

7.03 CURRENT CONFLICTS

7.03(a) Family Planning

At the present time, the battles between opposing sides of the family planning issue center around the concept of compulsory or forced family planning. On one side of the issue are proponents of compulsory limitation of family size, such as the group known as the Zero Population Growth. On the other side, the proponents vary from those who advocate a freedom of personal choice in family size to those who believe that parents should have the only say in limiting family size. Numerous well-known scientists and population experts can be found on either side, and proponents on each side of the issue can produce convincing arguments. Professor Ansley Coale believes that the nation's energies should be geared to attack the specific problems which the other side claims to be the result of over population (i.e., pollution, ghetto conditions, increased crime, etc.). Scientist Julian Huxley ominously sees overpopulation as the "most serious threat to the whole future of our species" (27).

7.03(b) Migration

As previously mentioned, the future migrations of new citizens into urban areas is expected to be primarily attributable to foreign immigrants. Hence, to limit migration, some form of control will have to be placed on immigration into the nation.

7.04 POSSIBLE IMPLEMENTATION OF PROGRAM IN NEVADA

Against this background it is easy to foresee the controversy which could result within Nevada from a statewide or areawide program of limiting family size, whether it would be a compulsory program or one which simply provided economic advantages to smaller families (e.g., the opposite of the present income tax dependency condition which now provides economic relief for larger families.) The other possible implementation of a program of family size limitation could come from a nationwide program effected by the federal government. However, at present the policy of the government seems to be opposed to any involvement in a program of this sort. President Nixon, in a 1969 speech to Congress on the subject of population, restated and re-emphasized the policy of freedom of choice as advocated by the three preceding presidents. Any change in this policy does not appear to be forthcoming at this moment. Federal officials seem to be holding to a wait-and-see attitude in an attempt to prevent making an important policy decision without clearly defined sanction from the populace.

7.05 EFFECT OF CONTROLLING FAMILY SIZE

Bureau of Census officials, prompted by an over estimate in the 1970 population, have now included a new forecast projection level. The Bureau dropped its highest projection level and added a category called "Series X" (28). This new projection level is equivalent to what would happen should all American females decide immediately that they would have only the necessary 2.1 births per childbearing woman for replacing the people who die. Even though it is not expected that all American women will immediately reduce the number of children to this rate, the Bureau felt that this new projection level was necessary because current population figures have been shown to be at the lower end of previous estimates.

Based on the "Series X" projection level, the Bureau has predicted that the national population would level out at 276 million by the year 2037. In the year 2000, the "Series X" birth rate would result in a total population of 250 million. If current population trends continue, the predicted populations for the years 2000 and 2037 are 301 million and 440 million, respectively. Consequently, the "Series X" projection level results in reductions in population for the years 2000 and 2037 of 17 percent and 37 percent respectively, from the populations predicted on the continuation of current trends.

The apparent disagreement between these population figures and those given in Section 2.01(b) is due to the fact that the "Series X" population projection assumes that net immigration to the U.S. will be zero while the projections in Section 2.01(b) assume that immigration to the U.S. will continue.

However, this prediction is national in scope; and it cannot be applied indiscriminately to individual states or sections within states. Nearly all states show a variation in growth rate from the average national growth rate. For example, Nevada's growth rate through the 1960's was many times the national average. One of the principal reasons that states show varied growth rates is the migration of citizens either out of or into the state. Nevada, in particular southern Nevada, has undergone a rapid growth in the 1960's because of the increase in business and industrial activity. Attendant with the business and industrial increase, more businessmen and industrial workers with their families have come to southern Nevada. The migration of people into the southern Nevada area accounted for a much greater share of the population increase than did births. Hence, in order to reduce the growth rate of southern Nevada, it would be necessary to develop a program of restricting migration into the area as well as a program of limiting births per family.

7.06 CONTROLLING MIGRATION

The problem of reducing the population growth rate within southern Nevada is a twofold problem. The reduction of the birth rate would not provide the solution by itself because of the migration into the area which can be expected to continue into the 1970's,

The problems associated with reducing the migration of people into the southern Nevada area may be as troublesome as those of reducing the birth rate. The freedom of movement between areas and the right to settle where one chooses appears to be a basic American freedom. The problem of restricting people from moving into a specific area consequently seems to be similar in nature to that of restricting family size in that both involve what have come to be understood as individual freedoms guaranteed by the Constitution. However, it would be possible to provide a means of restricting migration into southern Nevada without directly abrogating the citizen's right to move where he desires.

The restriction of migration could be accomplished ecnomically by controlling the growth of the base industries. If no new enterprises can be started, then there will be no additional job attractions drawing people to the community; and there will be no further secondary employment opportunities in service industries.

The two base industries of the Las Vegas metropolitan subarea are the gaming-entertainment industry and the military nuclear-research industry. There are many ways to stifle economic growth. For instance, in the case of heavy industry, stringent air pollution regulations could be adopted which preclude the establishment of new industry. Another action which would have an inhibitive effect would be to heavily tax industry thereby making operation less profitable in Nevada than in other states. Another method may be to essentially zone the southern portion of Nevada against the establishment of new industries or businesses; still another would be to simply not issue business licenses for the gaming-entertainment industry.

There are numerous methods of curtailing economic growth; however it is difficult to conceive of one which would not adversely affect the present residents of Nevada. For example, the many people who have invested in land in the state of Nevada would find that the land they bought at $2,000 an acre in anticipation of continued growth would possibly be worth only $200 per acre if that growth were not to occur. Another conceivable result of restricting the growth of the gaming-entertainment industry in Nevada would be for those people interested in the establishment of such industry to exert their influence to legalize gambling in an adjacent state; California for instance. More than 60 percent of all the visitors to Las Vegas live in the heavily populated southern California area. Should gambling be legalized in California, the effect upon the Nevada economy would be substantial. Assuming that 50 percent of the southern Californians preferred to do their gambling and be entertained in Las Vegas, this would still constitute an overall reduction in business and probable receipts of 30 percent. This reduction in profits would result in a corresponding reduction of employment in the gaming-entertainment industry of 30 percent and using the multiplier effect developed in Section 2.01(a), this would mean that an additional 26,000 people in Las Vegas would be jobless out of a total work force of 120,000. Unemployment would then rise from the present 5 percent to 26 percent.

Those citizens of southern Nevada advocating the restriction of population growth must realize that this course of action cannot be embarked upon with impunity.

There are many methods for limiting population and economic growth of southern Nevada. The methods discussed here do not exhaust the possibilities of this concept. It is hoped that this discussion will serve to demonstrate that in order to limit growth in southern Nevada, the present residents of the state must be willing to accept, in addition to the apparent benefits of limiting population, certain hardships and burdens which may be associated with this concept.

VIII PART 2 COMPARISON OF PLANS

COMPARISON OF PLANS

8.01 COSTS

When a community's water supply nears depletion, the cost for water can be expected to increase because of the necessity for finding other more expensive sources of supply. This economic phenomenon was demonstrated in the earlier sections of the report where the unit costs of additional supplies were shown to average about $190 per acre foot. This can be compared with the present-day unit costs which are nearer $26 per acre foot for water delivered to the point of distribution (production costs). After adding the cost to distribute the water to the ultimate consumer, the cost of the additional supplies would average $250 per acre foot compared to $90 per acre foot for the present supply.

Several factors are responsible for this great increase in unit cost of water. One reason is that the earlier water sources are utilized because of their economy. Hence, the water resources which are utilized to augment the original sources will usually be more expensive. The steady inflation of construction costs is another explanation for the rising unit costs. Over the past decade construction costs have increased about 70 percent. Still another factor which has been partly responsible for the rising costs of an additional water supply has been the increase in interest rates. In this study 7 percent interest rates were assumed to be most representative of the current economic situation. In 1960 interest rates for comparable loan conditions were about 4 percent. Hence, interest rates have been increased about 75 percent in the past decade. These three factors are probably not the only causes for the great increases in unit cost of water; however, they are the three which appear to bear the most responsibility.

Table VIII-1 presents a summary of the estimated unit costs for the water importation plans studied. The other alternative plans for eliminating the projected water supply deficiency, population dispersion, reduction in per capita consumption and population limitation, could not readily be put on a unit cost basis. The unit costs for the Snake-Colorado Project and the Modified Snake-Colorado Project are not on a strictly comparable economic basis to the other plans. The unit costs for these two regional water importation plans were determined by altering the economic analyses presented in the reports which proposed these plans.

The water importation plans listed in Table VIII-1 do not represent all the possible solutions to the Las Vegas Metropolitan subarea's water problem, but do give a representative sampling of the cost to obtain a supplemental water supply, Population dispersion, reduction of per capita consumption, and population limitation, are three other solutions which were investigated and reported upon. Other ground-water basins exist which may prove to be better suited as sources of supply for importation to Las Vegas. More exotic solutions such as floating icebergs to points off the California coast or laying a thin-wall pipe on the continental shelf to connect the northern areas of surplus with the southern areas of deficiency may one day prove to be the panacea for supplying the arid southwest.

8.02 EFFECTS ON AREA OF ORIGIN

Considerations must be made of effects other than unit costs if the entire water supply situation is to be brought into focus. The water importation plans all involve the removal of part of a valuable resource from one region for use in another. In the interstate plans, the source areas from which the water would be obtained are beyond the boundaries of the State. No consideration has been given to the source area in these plans because this would be considered by the states together when they negotiate the terms of an interstate movement of water. However, the intrastate water plans all involve reducing the water resources of regions within the State of Nevada; hence, they have been examined more closely to determine the effects on the source areas.

Nearly all of southern Nevada, with the exception of the Las Vegas Metropolitan subarea, has experienced very little development. Farming, government employment, and roadside business are the principal economic bases of these relatively undeveloped areas. The implementation of any of the intrastate plans would in most cases severely reduce the farming because water rights would have to be purchased from the farmers thus curtailing their irrigation activity. However, the effect on the other two base industries would

COMPARISON OF PLANS

be insignificant because there would be adequate water supplies available for the non-farming population. Also, it appears that the water supply would be sufficient for the expected population growth of all the source subareas. The one exception of this is Pahranagat Valley, where it is expected that population may not grow to the probable estimate of 2,500 by year 2020 if Pahranagat Valley is used as a source of supply for the Las Vegas Metropolitan area.

Besides an economic consideration, there are non-economic factors which are brought into the picture. Environmental factors are significant in the Amargosa Desert and Pahranagat Valley alternatives. In the case of the Amargosa Desert alternative, there is a probability that a very rare species of fish, the pupfish, would be eliminated. This fish is found only in this area, and the lowering of the water table there would dry up the water holes where these fish now live. Unless remedial action is taken, these fish would disappear if the Amargosa Desert alternative water plan were to be implemented.

Another possible effect related to the implementation of the Amargosa Desert alternative would be concerned with the movement of radioactive wastes from the Nevada Test Site. Ground water studies have indicated that it is possible that radioactive wastes may one day be found in the ground water of the Amargosa Desert (2) since the ground water of the Nevada Test Site which has been polluted by underground nuclear explosions appears to move toward the Amargosa Desert. However, the time required for ground water to move from the Nevada Test Site to the Desert is on the order of many years. Thus, it is uncertain whether radioactive waste would cause a problem should this alternative be chosen.

An additional environmental factor which should be

TABLE VIII–1

COMPARISON OF UNIT WATER COSTS
($/Ac Ft)

COMPARISON OF UNIT WATER COSTS ($/Ac. Ft.)

Plan	Cost Delivered to Las Vegas Valley L.G.R.*	H.G.R.*	Cost of Water Including Distribution Costs*** L.G.R.	H.G.R.
Cost of Water in L.V.V. today			90	
Intrastate Plans				
Pahrump Valley	168	186	230	248
Amargosa Desert	225	270	287	332
Railroad Valley	252	268	314	330
Pahranagat Valley	178	214	240	276
Virgin Valley	63	63	125	125
Interstate Plans **				
Snake Colorado Project	175		240	
Modified Snake-Colorado Project	190		255	
Desalinization	200		265	

* A unique unit cost is specified by one population estimate, range of unit cost indicates the range expected on the basis of high and low population estimates.
H.G.R. = High Growth Rate L.G.R. = Low Growth Rate

** Price for water for interstate plans is unaffected by population growth rates of Nevada.

*** Cost to ultimate consumer.

considered is related to the Pahranagat Valley alternative. If this plan is implemented, the green vegetation of that valley would be severely reduced. The lowering of the water table would eventually increase the depth to water to the point where the vegetation could not reach it, and thereby the water supply to their roots would be cut off. The upper and lower Pahranagat Lakes, extensively utilized as a wildlife refuge, would become dry. Also, there is the likelihood that the springs supplying the Muddy River would be reduced in capacity or become dry.

8.03 EFFECT ON AREA OF USE

The availability of a water supply for the Las Vegas Metropolitan subarea would insure that the expected growth of the subarea would not be inhibited by an insufficient water supply. Of course, by itself, this does not guarantee that this growth will be realized. It only eliminates the growth restriction placed on a community by an insufficient water supply.

8.04 ADAPTABILITY TO LONG–RANGE PLANS BEYOND 2020

As was mentioned earlier, the intrastate water plans are short-range or immediate solutions to the predicted water shortage. These plans would delay the time of the shortage so that other long-range plans could be devised and implemented. At the end of the project life of the intrastate plans the water supply from the source area will be terminated; hence, it would be necessary to replace that supply. The interstate alternatives and the reduction in per capita consumption and the no growth alternative are plans which would not be terminated at the end of the project life. In contrast, the interstate regional water importation plans are long-range projects and could be expected to solve the water problem well past 2020.

Should one of the intrastate alternatives be chosen, it should not be incompatible with possible long-range plans. At this point in time, however, it would be extremely hazardous to state unequivocally that the intrastate plans would or would not be compatible. Because the long-range plans are by no means past a very preliminary analysis, it is doubtful where the facilities for the long-range projects would be located. Hopefully, the long-range plans would be designed with the intention of utilizing the facilities of the intrastate plans.

8.05 SUMMARY AND COMPARISON OF UNIT WATER COSTS

In summary, the unit water costs of the various water supply alternatives are summarized in Table VIII-1 for easy comparison of the various plans and the present average cost of water to the Las Vegas Valley consumer.

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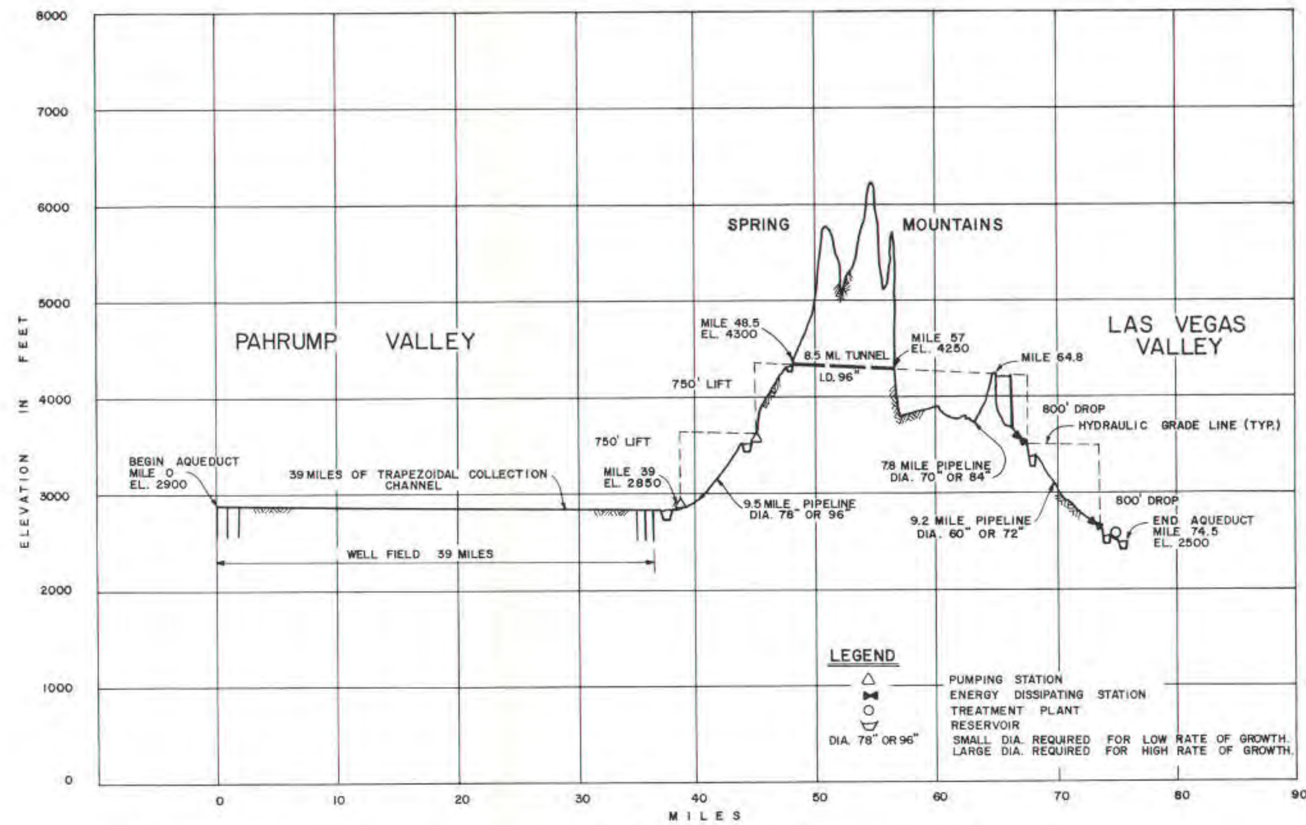
State of Nevada

WATER PLANNING REPORT

ESTIMATED COSTS OF
PAHRUMP TO LAS VEGAS AQUEDUCT

DESCRIPTION	Construction Cost ($) Q = 216 cfs	Q = 350 cfs
Wells	2,480,000	3,950,000
Collection System	12,560,000	15,120,000
P. S. Forebay	1,890,000	3,150,000
Pump Station (2)	11,870,000	19,100,000
P. S. Afterbay (2)	1,890,000	3,150,000
Tunnel	23,500,000	23,500,000
Pipeline	18,370,000	20,930,000
Reservoirs (2)	1,890,000	3,150,000
Dam & Reservoir	8,920,000	8,930,000
Energy Dissipators (2)	3,150,000	6,300,000
Treatment Plant	12,970,000	19,600,000
Terminal Storage	3,820,000	6,700,000
Power Transmission	3,820,000	4,860,000
Telemetry	1,575,000	4,100,000
Subtotal	$108,705,000	$142,540,000
Contingencies at 20%	21,741,000	28,508,000
Subtotal - Construction Cost	$130,446,000	$171,048,000
Engineering, Administration, Inspection and Bond Costs at 15%	19,567,000	25,657,000
Interest during Construction at 14%	18,262,000	23,947,000
Total Cost of Project Facilities	$168,275,000	$220,652,000
Estimated Reparation Cost in Pahrump	17,280,000	17,280,000
GRAND TOTAL PROJECT COST	$185,555,000	$237,932,000

NOTE: Cost estimates prepared using 1970 prices ENR index - 1400



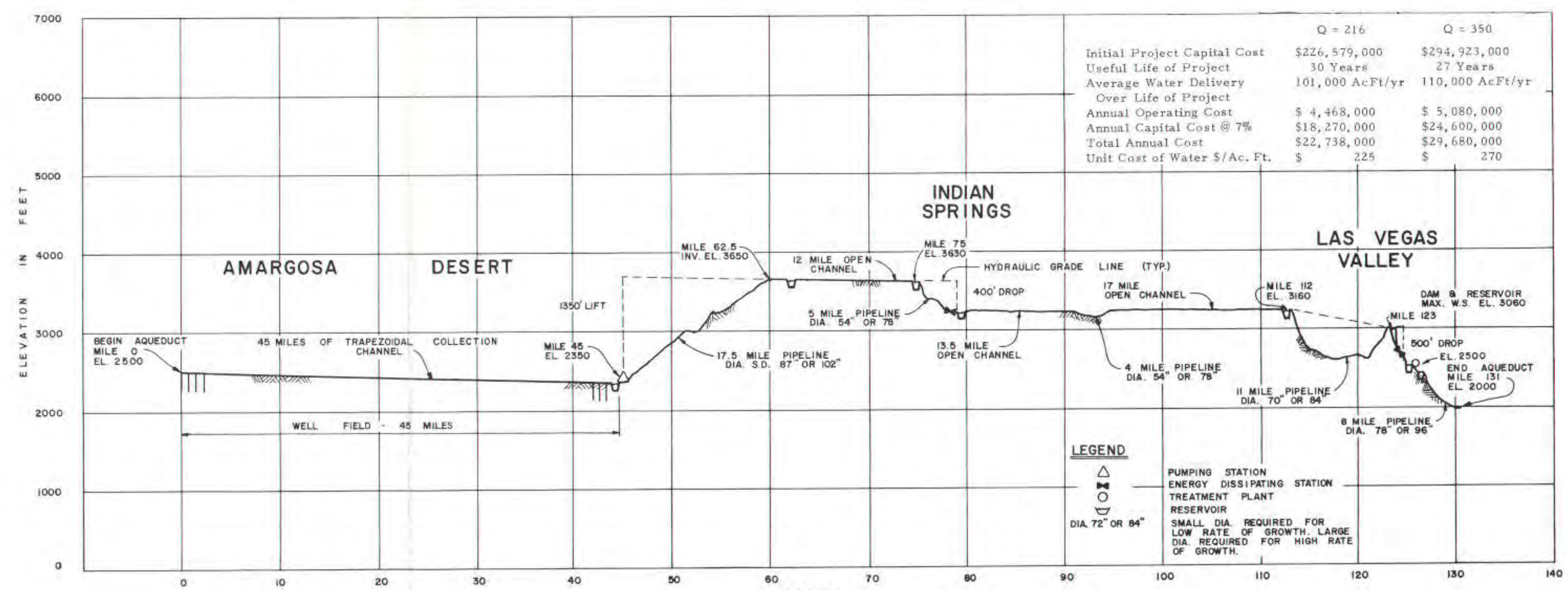
(FIG. III-6) PROFILE OF PAHRUMP TO LAS VEGAS AQUEDUCT

	Q = 216	Q = 350
Initial Project Capital Cost	$185,555,000	$237,932,000
Useful Life of Project	39 Years	33 Years
Average Water Delivery Over Life of Project	108,000 AcFt/yr	127,500 AcFt/yr
Annual Operating Cost	$ 4,243,000	$ 5,000,000
Annual Capital Cost @ 7%	$13,900,000	$18,650,000
Total Annual Cost	$18,143,000	$23,740,000
Unit Cost of Water $/Ac. Ft.	$ 168	$ 186

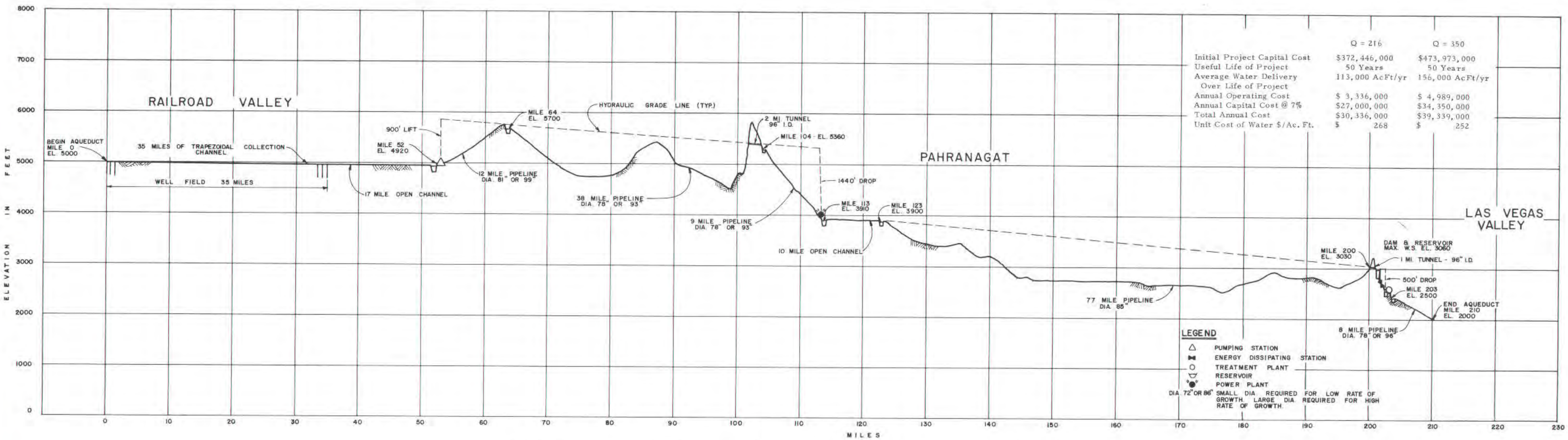
ESTIMATED COSTS OF
AMARGOSA TO LAS VEGAS AQUEDUCT

DESCRIPTION	Construction Cost ($) Q = 216 cfs	Q = 350 cfs
Wells	2,540,000	4,040,000
Collection System	14,300,000	17,350,000
P.S. Forebay	1,940,000	3,230,000
Pump Station	10,910,000	17,600,000
Reservoir (4)	5,810,000	9,670,000
Canals	15,380,000	19,500,000
Pipelines	35,100,000	42,300,000
Dam & Reservoir	14,000,000	14,000,000
Energy Dissipators (2)	2,910,000	5,910,000
Treatment Plant	13,300,000	20,070,000
Terminal Storage	3,930,000	6,850,000
Facilities for Blending	11,570,000	14,600,000
Power Transmission	5,940,000	6,340,000
Telemetry	2,150,000	2,470,000
Subtotal	$139,780,000	$183,930,000
Contingencies at 20%	27,956,000	36,786,000
Subtotal - Construction Cost	$167,736,000	$220,716,000
Engineering, Administration, Inspection and Bond Costs at 15%	25,160,000	33,107,000
Interest during Construction at 14%	23,483,000	30,900,000
Total Cost of Project Facilities	$216,379,000	$284,723,000
Estimated Reparation Cost in Amargosa Desert	10,200,000	10,200,000
GRAND TOTAL PROJECT COST	$226,579,000	$294,923,000

	Q = 216	Q = 350
Initial Project Capital Cost	$226,579,000	$294,923,000
Useful Life of Project	30 Years	27 Years
Average Water Delivery Over Life of Project	101,000 AcFt/yr	110,000 AcFt/yr
Annual Operating Cost	$ 4,468,000	$ 5,080,000
Annual Capital Cost @ 7%	$18,270,000	$24,600,000
Total Annual Cost	$22,738,000	$29,680,000
Unit Cost of Water $/Ac. Ft.	$ 225	$ 270



(FIG. III-7) PROFILE OF AMARGOSA TO LAS VEGAS AQUEDUCT



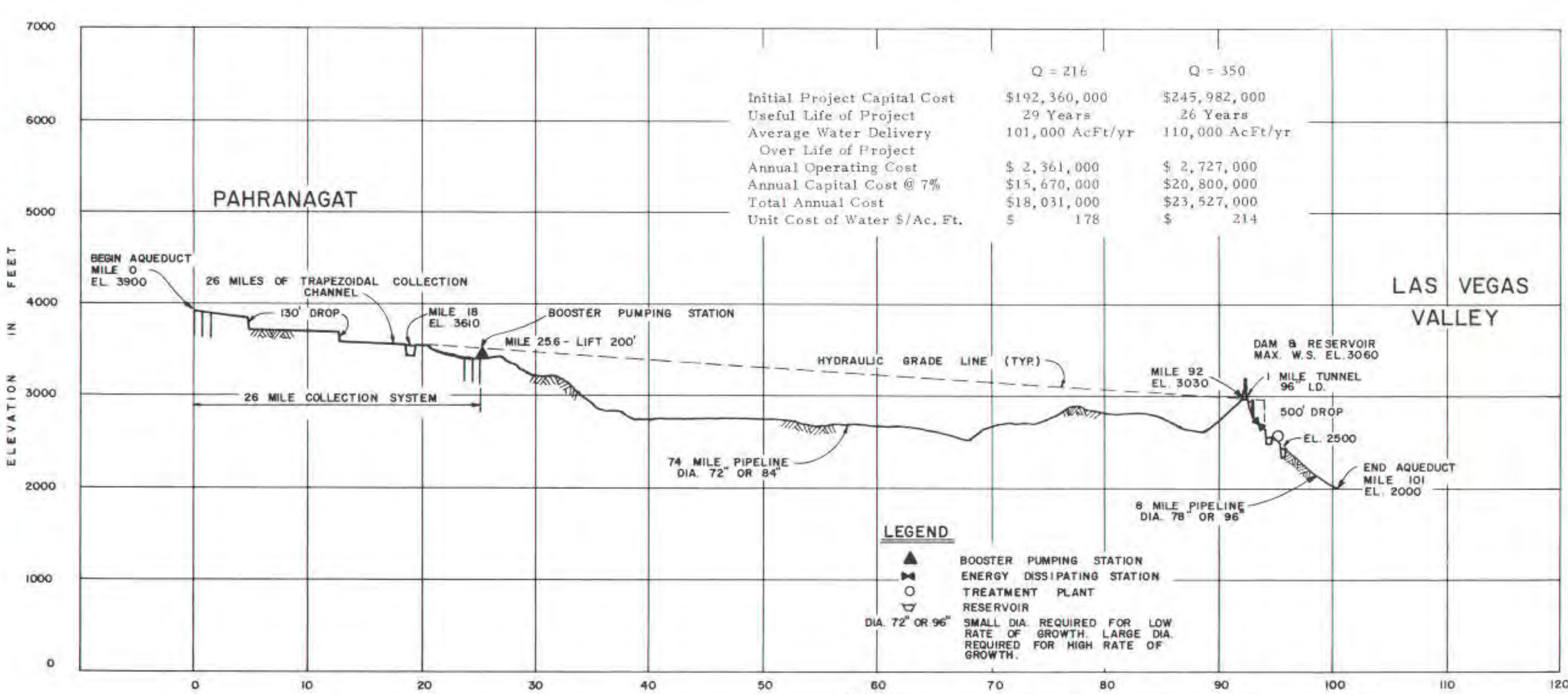
	Q = 216	Q = 350
Initial Project Capital Cost	$372,446,000	$473,973,000
Useful Life of Project	50 Years	50 Years
Average Water Delivery Over Life of Project	113,000 AcFt/yr	156,000 AcFt/yr
Annual Operating Cost	$ 3,336,000	$ 4,989,000
Annual Capital Cost @ 7%	$27,000,000	$34,350,000
Total Annual Cost	$30,336,000	$39,339,000
Unit Cost of Water $/Ac. Ft.	$ 268	$ 252

(FIG. III-8) PROFILE OF RAILROAD TO LAS VEGAS AQUEDUCT

ESTIMATED COSTS OF
RAILROAD VALLEY TO LAS VEGAS AQUEDUCT

DESCRIPTION	Construction Cost ($) Q = 216 cfs	Q = 350 cfs
Wells	2,710,000	4,330,000
Collection	13,300,000	15,700,000
P. S. Forebay	2,070,000	3,450,000
Pump Station	7,700,000	12,570,000
P. S. Afterbay at Mile 64	5,960,000	9,650,000
P. P. Forebay	2,070,000	3,450,000
Power Plant	12,470,000	20,200,000
P. P. Afterbay	1,035,000	1,750,000
Pipeline Inlet	460,000	575,000
Canals	10,300,000	13,100,000
Pipeline	116,600,000	138,300,000
Tunnels	7,900,000	7,900,000
Reservoir at Mile 201	14,950,000	14,950,000
Energy Dissipator	1,720,000	3,450,000
Treatment Plant	14,200,000	21,460,000
Terminal Storage	4,200,000	7,350,000
Power Transmission	6,460,000	7,760,000
Telemetry	2,880,000	3,450,000
Subtotal	$227,185,000	$289,395,000
Contingencies at 20%	45,437,000	57,879,000
Subtotal - Construction Cost	$272,622,000	$347,274,000
Engineering, Administration, Inspection and Bond Costs at 15%	40,893,000	52,091,000
Interest during Construction at 21%	57,251,000	72,928,000
Total Cost of Project Facilities	$370,766,000	$472,293,000
Estimated Reparation Cost in Railroad Valley	1,680,000	1,680,000
GRAND TOTAL PROJECT COST	$372,446,000	$473,973,000

NOTE: Cost estimates prepared using 1970 peices ENR index - 1400



	Q = 216	Q = 350
Initial Project Capital Cost	$192,360,000	$245,982,000
Useful Life of Project	29 Years	26 Years
Average Water Delivery Over Life of Project	101,000 AcFt/yr	110,000 AcFt/yr
Annual Operating Cost	$ 2,361,000	$ 2,727,000
Annual Capital Cost @ 7%	$15,670,000	$20,800,000
Total Annual Cost	$18,031,000	$23,527,000
Unit Cost of Water $/Ac. Ft.	$ 178	$ 214

(FIG. III-9) PROFILE OF PAHRANAGAT TO LAS VEGAS AQUEDUCT

ESTIMATED COSTS OF
PAHRANAGAT TO LAS VEGAS AQUEDUCT

DESCRIPTION	Construction Cost ($) Q = 216 cfs	Q = 350 cfs
Wells	2,540,000	4,040,000
Collection System	10,100,000	16,300,000
Booster P.S.	1,860,000	2,600,000
Reservoir at Mile 18	1,930,000	3,220,000
Pipeline	64,400,000	77,100,000
Tunnel	2,470,000	2,470,000
Dam and Reservoir at Mile 93	14,000,000	14,000,000
Energy Dissipator	1,290,000	20,100,000
Treatment Plant	13,300,000	6,860,000
Terminal Storage	3,920,000	3,220,000
Power Transmission	2,580,000	2,150,000
Telemetry	1,610,000	2,580,000
Subtotal	$120,000,000	$154,640,000
Contingencies at 20%	24,000,000	30,928,000
Subtotal - Construction Cost	$144,000,000	$185,568,000
Engineering, Administration, Inspection and Bond Costs at 15%	21,600,000	27,835,000
Interest during Construction at 14%	20,160,000	25,979,000
Total Cost of Project Facilities	$185,760,000	$239,382,000
Estimated Reparation Cost in Pahranagat	6,600,000	6,600,000
GRAND TOTAL PROJECT COST	$192,360,000	$245,982,000