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WATER RESOURCES IN SOUTHERN NEVADA

CNWRA TASK ACTIVITY 3702-002-305-604

FINAL TECHNICAL REPORT

By

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1.0 INTRODUCTION

1.1 TASK ASSIGNMENT

The Nuclear Regulatory Commission (NRC) Staff has requested support from the Center for Nuclear Waste Regulatory Analyses (Center) in the development of a Staff Technical Position on Natural Resources Assessment Methods. The Center was directed to identify the attributes of acceptable methodologies for the assessment of natural resources of a proposed high-level waste repository site, with particular consideration being given to a site with a geologic setting similar to that of the Yucca Mountain site in the southern Basin and Range physiographic province.

As part of the overall natural resource assessment initiative, the Center has directed Adrian Brown Consultants to prepare three technical reports addressing specific aspects of the assessment of ground water potential. The topics to be addressed and their status are as follows:

- **Ground water classification with respect to the Individual and Ground Water Protection requirements of 40 CFR Part 191.** This report was submitted to the Center on November 9, 1989.
- **Projections of regional ground water needs in southern Nevada.** This is the topic of this technical report.
- **Identification of ground water resource assessment methodologies.** This report was submitted to the Center on December 6, 1989.

This second task entails a review of available information on long-term projections of regional groundwater needs in southern Nevada. The following is a review of water resources in southern Nevada and the current and projected water demands on these resources. The area considered for this report is shown on Figure 1.

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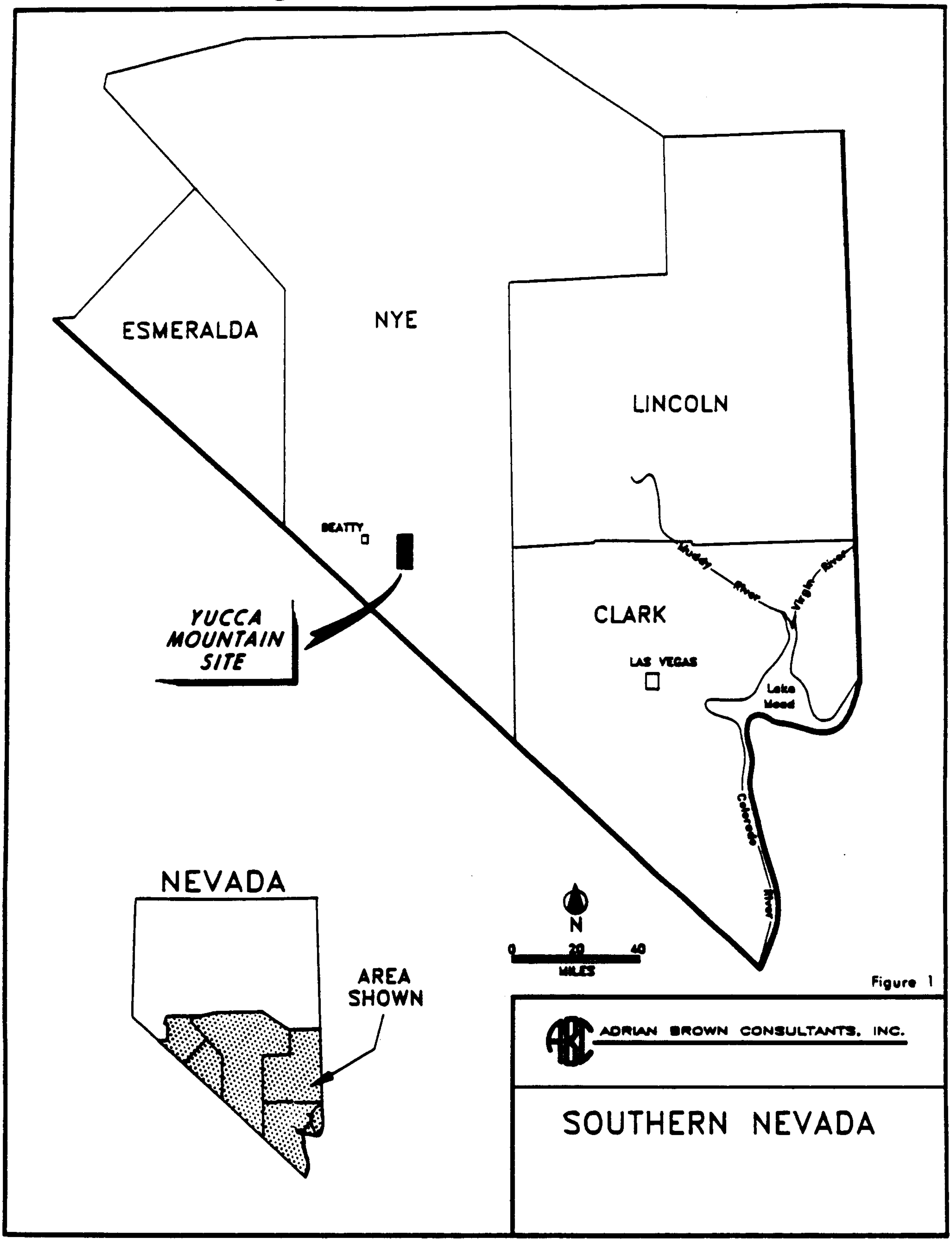

Figure 1

SOUTHERN NEVADA

1.2 LIMITATIONS ON PROJECTIONS

Nevada's state economists have projected population growth to the year 2010. In general, economists believe 20-year population predictions for resource and economic planning are reasonably accurate. Planning beyond a 20-year time frame introduces large uncertainties and is not felt to be necessary for Nevada's economic and resource planning purposes. This report looks at the current water resources, existing water use and water-use projections based on the State's current 20-year population predictions. Predictions beyond 20 years are not attempted due to the large uncertainty associated with such predictions.

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2.0 RELATIONSHIP TO THE NUCLEAR REGULATORY COMMISSION REGULATIONS

The Nuclear Regulatory Commission (NRC) regulations relevant to this report can be found within 10 CFR Part 60, Subparts B and E. Subpart B pertains to the actual documentation which must be submitted to the NRC for licensing of a high-level nuclear waste repository (HLWR). Subpart E is relevant because it establishes performance objectives and site and design criteria which will support, if satisfied, the licensing of an HLWR. Portions of these regulations relevant to this report are given below:

> 60.21(c) The Safety Analysis Report shall include: ... (13) an identification and evaluation of the natural resources of the geologic setting ...
>
> 60.122(c) The following conditions are potentially adverse conditions if they are characteristic of the controlled area or may affect isolation within the controlled area.
>
> > (2)Potential for foreseeable human activity to adversely affect the groundwater flow system, such as groundwater withdrawal, extensive irrigation ... or construction of large scale surface water impoundments.
> >
> > (5)Potential for changes in hydrologic conditions that would affect the migration of radionuclides to the accessible environment, such as changes in hydraulic gradient, average interstitial velocity, storage coefficient, hydraulic conductivity, natural recharge, potentiometric levels, and discharge points.
> >
> > (17)The presence of naturally occurring materials ... within the site, in such form that: (i) Economic extraction is currently feasible or potentially feasible during the foreseeable future...

Although the data needs for each regulatory requirement are similar, the objective of each is logically different. Section 60.21(c) is concerned with the potential impacts of the repository on the natural resources whereas for Section 60.122(c), this objective is reversed. Section 60.122(c) is concerned with the potential impacts of development and exploitation of natural resources on the repository performance. This report addresses occurrence of water resources (60.21(c)) in Nevada and the potential for exploitation of these water resources in the near future (60.122(c)).

3.0 WATER RESOURCES AVAILABLE IN SOUTHERN NEVADA

Present water supply sources available in Southern Nevada include groundwater from the several extensive shallow alluvial aquifers, groundwater from generally deep carbonate aquifers, Colorado River water, and limited surface water exclusive of main stem Colorado River water. These sources are discussed below.

3.1 GROUNDWATER RESOURCES

Although Nevada, and particularly southern Nevada, has a dearth of surface streams accessible for water supply, an abundant water supply is available for one time use from groundwater in storage in all of the valleys where it is conceivable a need would exist. The exception to this is the Las Vegas metropolitan area. A study conducted by Montgomery Engineers (State of Nevada, 1971) concluded the only area with a significant water deficiency (present and future) in southern Nevada would be in the Las Vegas Metropolitan area.

The extent to which groundwater in storage is exploited is largely limited by the water policy of the state. State policy is usually based on an evaluation of population growth and designated usage. The State Engineer's current policy is based on a "safe yield" concept (e.g. Todd, 1959). This construct limits water rights to the estimated perennial yield. When the perennial yield of a basin is fully appropriated, the basin becomes "designated" by the State Engineer and no new water rights will be issued. Several designated groundwater basins exist in southern Nevada, as shown on Figure 2. For these designated basins, the groundwater withdrawn may still exceed the safe yield if the State Engineer determines exploitation is necessary for the common good. This provides some flexibility within Nevada's current water policy. Alternative water policies are discussed in Section 4.2.2.

Estimates of available groundwater in the southern portions of Clark, Esmeralda, Nye, and Lincoln counties are given in Table 1.[1] Perennial yield estimates are, in general, for the shallowest aquifer (i.e., alluvial aquifer). Storage estimates are defined by the water in storage in the upper 100 feet of saturation. As shown in Figure 3, perennial yield and storage estimates (Table 1) are not available for all hydrographic basins in Esmeralda, Lincoln, and Nye counties. Based on the current safe yield concept, all of the perennial yield is subject to use. The data in Table 1 show

[1]*Values in Table 1 are approximate and may be in error by as much as thirty percent (State of Nevada, 1982).*

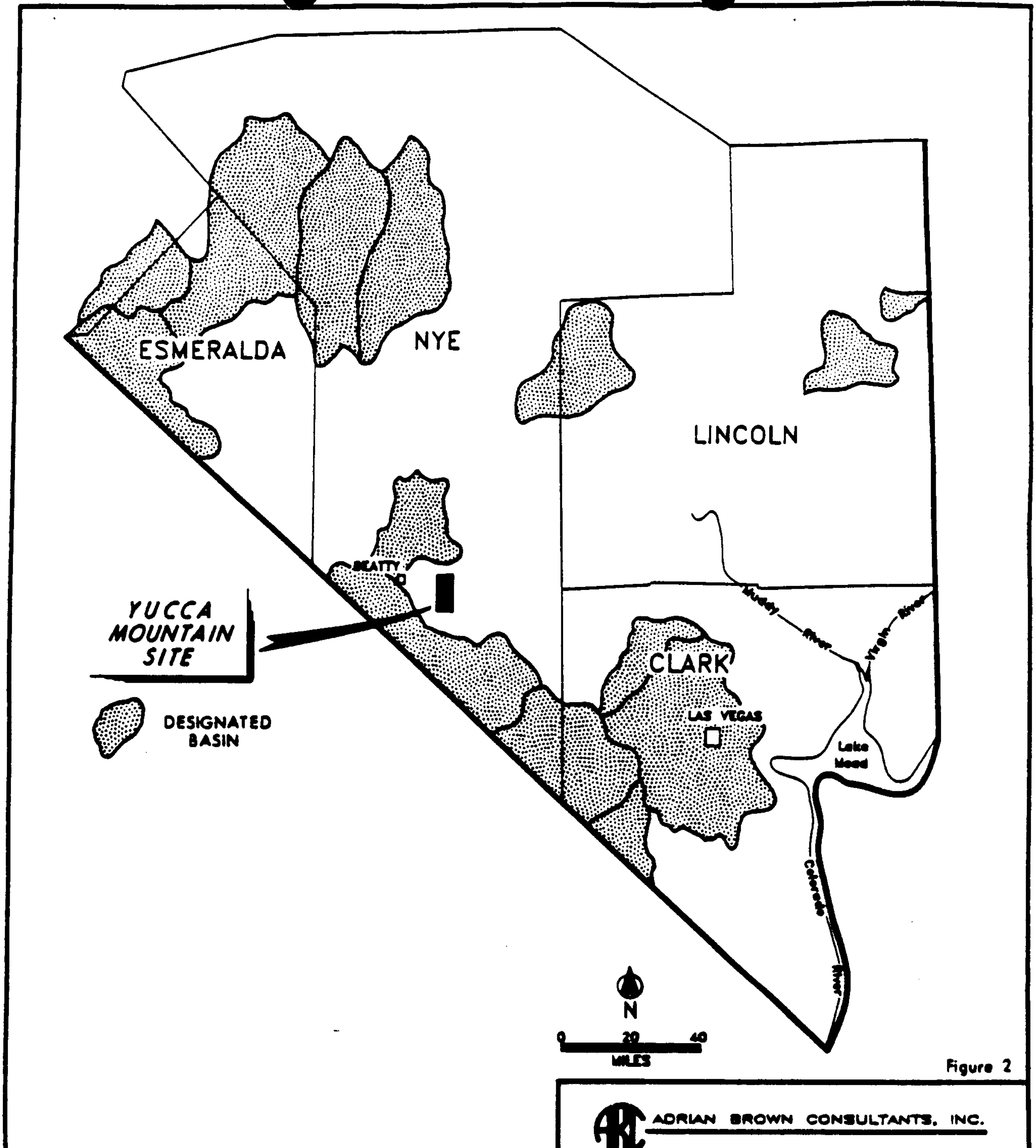

Figure 2

DESIGNATED GROUNDWATER BASINS IN SOUTHERN NEVADA

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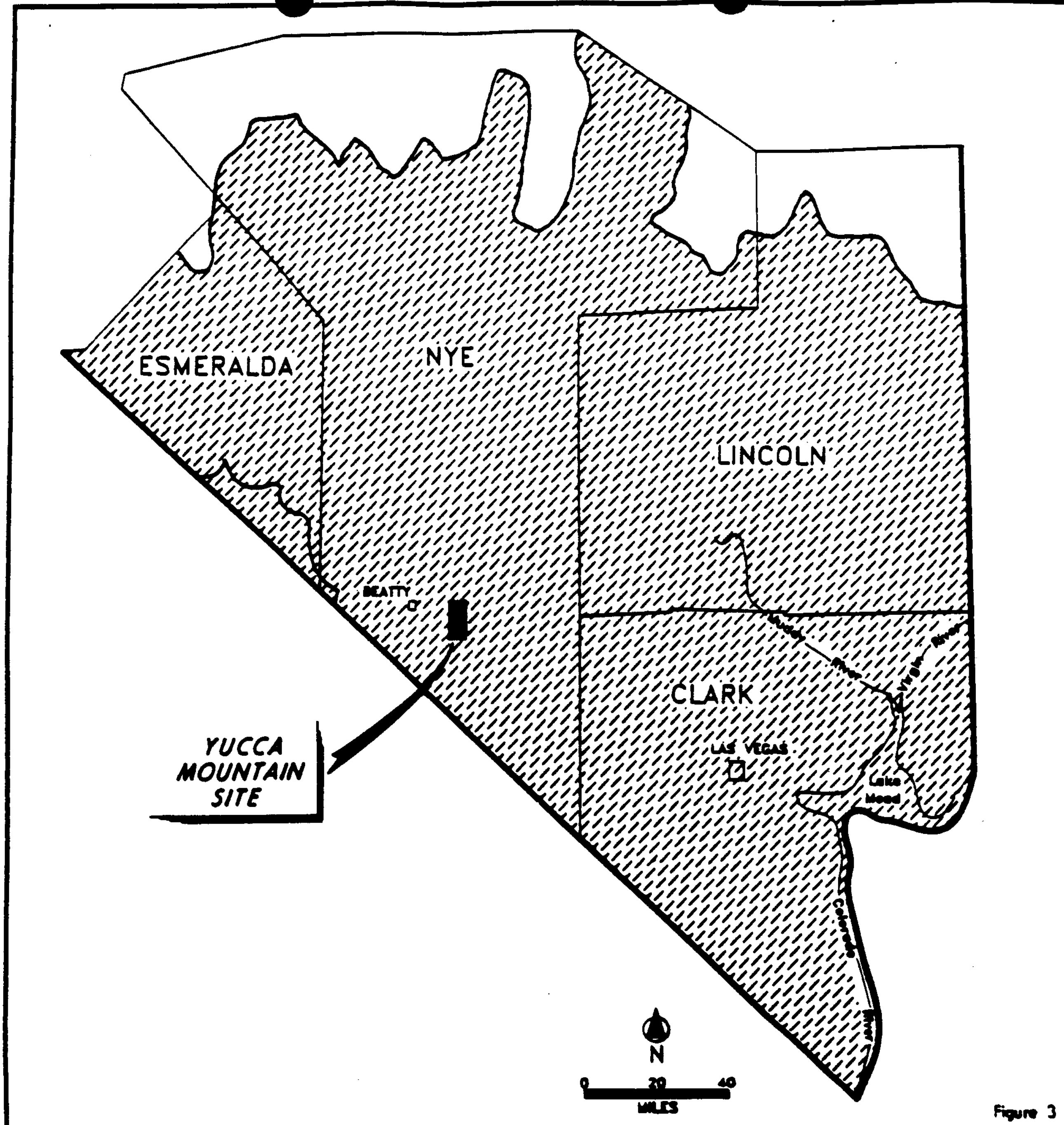

Figure 3

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AREAS INCLUDED IN AVAILABLE GROUNDWATER ESTIMATES (Table 1)

Table 1. Groundwater Availability by County

County Name	Perennial Yield (acre-feet/year)	Water in Storage (acre-feet)
Clark	203,625	17,856,350
Esmeralda	67,350	4,225,300
Lincoln	168,050	21,628,350
Nye	214,350	28,741,350
TOTAL	653,375	72,451,350

(State of Nevada, 1982)

that groundwater recharge (perennial yield) is limited. As is also shown in Table 1, a considerable amount of groundwater in storage is easily available, but only for one-time use. Based on today's (1990) southern Nevada population (740,000) and a per capita consumption of 475 gallons per day (State of Nevada, 1971), this amount of water in storage (excluding perennial yield) could sustain the current population until 2200. If we were to assume a per capita usage of 780 gallons per day (Table 2) based on ABC's calculation, water in storage (excluding perennial yield) could only sustain the current population until 2100.

Table 2. Current (1985) Water Use by County

County Name	Population	Domestic (gpd/person)	Agricultural/ Commercial (gpd/acre)	Per capita use (gpd/person)
Clark	570,000	340	8,400	490
Esmeralda	1,400	150	4,400	26,000
Lincoln	4,200	220	3,800	16,000
Nye	15,000	210	3,900	5,300
weighted average =		330	4,700 (430 gpd/person)	780[2]

To date, all groundwater developed in the Las Vegas Valley has come from the alluvial aquifers. Carbonate bedrock underlies the saturated valley-fill of many Nevada hydrographic basins. According to Mifflin (1968) and State of Nevada (1982), little is known in many of these basins regarding the quantity, quality and interconnectivity of the deep carbonate aquifers; however, it is believed a considerable amount of water could be mined from these aquifers. In most places, the carbonate aquifers are at great depth (735-4000 feet), but in a few places (e.g., parts of the Nevada Test Site and the localized areas of the Amargosa Desert)

[2] *Numbers may not add to totals due to independent rounding.*

these aquifers are relatively shallow and are utilized for water supply (Winograd, 1975). Saturated thickness for these carbonate aquifers is known to range from a few hundred to several thousand feet thick in southern Nevada (Mifflin, 1968). Due to the great depth of the carbonate aquifers in some areas (including the Las Vegas basin), widespread use of water from these deep aquifers is not currently considered economically feasible (State of Nevada, 1982).

3.2 SURFACE WATER RESOURCES

Historically, southern Nevada has depended heavily on the Colorado River for its water supply. Current surface water rights under the Colorado River Compact limit the availability of water from the Colorado River to Nevada at 300,000 acre-feet per year (Wallen, personal communication, 1989). Based on actions of the compact and litigation such as Arizona v. California (e.g., U.S. 546, 1963; 439 U.S. 419, 1979; 460 U.S. 605, 1983)[3] there exists the threat of reallocation of these surface water rights which could potentially reduce Nevada's Colorado River allocation and increase the need for exploitation of the state's groundwater resources.

Due to southern Nevada's arid climate, there are very few perennial streams other than the Colorado River. Although the streams are dry nearly all of the year, they may carry a significant volume of water after a heavy thunderstorm. Tables 3 and 4 summarize stream and lake data pertinent to Nevada's southern counties. This compilation indicates only 72 streams and 58 water bodies total in Clark, Esmeralda, Lincoln, and Nye counties. Known spring discharge data, given in Table 5, is assumed to be a part of the data given in Tables 3 and 4. The spring outflow may exceed the stream flow due to the arid climate and rapid evapotranspiration (U.S. Department of Energy, 1988).

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[3] *Note that reallocation issues exist not only between the various States, but also between the States and the Indian Tribes on the lower Colorado. For example, Justice Black's 1963 majority opinion awarded five lower basin Tribes (representing only about 3,500 people) more than 10% of the entire annual lower basin share of the Colorado River, or about three times the entire amount granted to Nevada. Note that the new Indian allocations, determined on the basis of the Report of the Special Master, Simon H. Rifkind (Arizona v. California, 54, 265, 1960), are to be subtracted from the States in which the reservations are located, and that these Winters rights are considered senior to all other rights in the lower basin.*

Table 3. Stream Inventory by County

County Name	Quantity	Total Length (miles)	Stream Flow (ac-ft/yr)
Clark	5	69.0	92,000
Esmeralda	9	50.3	55,200
Lincoln	11	91.2	NA[4]
Nye	47	281.7	21,300

(Walstrom, 1973)

Table 4. Lake, Reservoir and Pond Inventory by County

County Name	Quantity	Total Volume (acre-feet)
Clark	7	4,153
Esmeralda	5	32,700[5]
Lincoln	18	33,581
Nye	28	7,012

(Walstrom, 1973)

Table 5. Major Springs of Southern Nevada

County Name	Quantity	Spring Flow (ac-ft/yr)
Clark	8+	39,000
Esmeralda	12	2,900
Lincoln	10+	36,000
Nye	31+	64,000

(State of Nevada, 1982)

Of the five streams listed in Clark County, one is the Colorado River and two are direct tributaries to the Colorado River (Virgin River and Muddy River - Figure 1). The reported stream flow data for Clark County are collected from the two tributaries at their exit points into Lake Mead (State of Nevada, 1982). Upstream from Lake Mead, water from the tributaries contributes to agricultural, domestic and industrial water supply systems.

Of the seven water bodies listed for Clark County in Table 4, one is Lake Mead and another is Lake Mojave. The water volumes reported excluded these lakes since they are part of the Colorado River appropriations. Evidently, excluding the Colorado River

[4] *NA = data not available*

[5] *Represents water-body capacity, not actual volume*

resources, the quantity of surface water in Clark County is limited (say, 92,000 acre-feet/year).

Stream flows of 76.2 cubic feet per second (55,200 acre-feet/year) are reported in Esmeralda County. Flows were surveyed in June (when spring runoff is occurring) in the White Mountains; one would expect the stream flow volume to decrease considerably if reported on a per annum basis. Unfortunately, annual (or gage) data was not collected on many of the streams. For estimation of water available for consumptive use annually, one might assume an annual runoff in this region of 0.2 inches (Langbein et al., 1949). Based on this assumption, annual stream flows in Esmeralda County would run about 38,000 acre-feet/year. No actual water volumes are recorded for the five water bodies reported in Esmeralda County, but surveys of average depth and surface area allow for an estimate of the water volume on the surface in the county of 32,700 acre-feet/year.

Lincoln County reports 91.2 miles of streams. Stream flows were not reported, but the State reports spring flows of 36,000 acre-feet/year in Lincoln County (Table 5). The county has several mountain ranges with large topographic relief, two flood control projects, and several reservoirs. For lack of any other available data, one might assume an annual runoff in Lincoln County of about 0.2 inches (Langbein et al., 1949). Stream flows would then run about 113,000 acre-feet/year. Water volume reported in the county's lakes, reservoirs, and ponds is approximately one-third this amount, or 33,581 acre-feet/year.

Nye County is the largest county in southern Nevada with respect to surface area. Several mountain ranges in the northern part of the county account for a number of the streams and miles reported. The county has claim to numerous springs (Table 5), but much of the spring outflow is lost to evapotranspiration. No stream flows are reported with a greater than 5 cubic feet per second (3600 acre-feet/year) flow, the highest spring discharge recorded is 15 cubic feet per second (11,000 acre-feet/year), and the total water-body volume is small. However a large percentage (about 70%) of the water body data did not report volumes. One might assume some part of the total spring and stream flows (say, 50,000 acre-feet per year) is available for consumptive use.

Although there is high uncertainty in the surface water data collected (based on methodology, missing data, etc.), it would be reasonable to assume 200,000 to 250,000 (somewhat less than flows reported above) acre-feet per year of surface water exclusive of the Colorado River is available in southern Nevada for water supply. In 1985 only about 120,000 acre-feet per year of this flow was being utilized. Based on a population of 740,000 and an expected water demand of .87 acre-feet per person per year (780 gallons/day, see Table 2), the surface-water resources of the four county area (excluding the Colorado River) are only sufficient for about 130 days per year.

4.0 CURRENT AND PROJECTED WATER USE

The following estimates of current and projected water use are based on hydrologic data collected by the State Engineer and population estimates and forecasts compiled by the Nevada State Demographer (data compiled by USGS, State Engineer, and the Nevada State Demographer, 1989, unpublished, on file at ABC office and Nevada State Engineer's office). Figure 4 shows the estimated population trends by county to 2010. As shown, Clark and Nye counties (Figures 4a and 4d) expect considerable growth in the next 20 years. Lincoln and Esmeralda counties (Figures 4b and 4c) expect some limited growth. As always, large uncertainties are persistent in population forecasts, based on economic policies at both the state and federal levels (e.g. Nevada will continue to urge industry growth, gaming will continue to be legal in Nevada, the national economy will continue to grow, etc.). Predictions of water usage are based on population trends, current land irrigation, and proposed industrial growth.

Figure 4a. Estimated Population Trends for Clark County

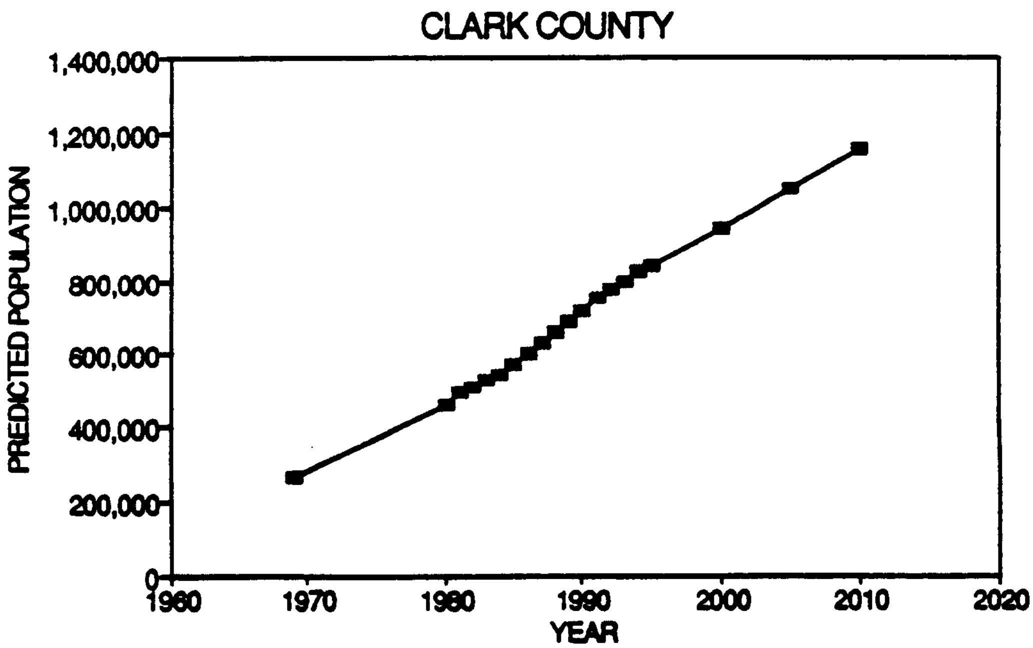


Figure 4b. Estimated Population Trends for Esmeralda County

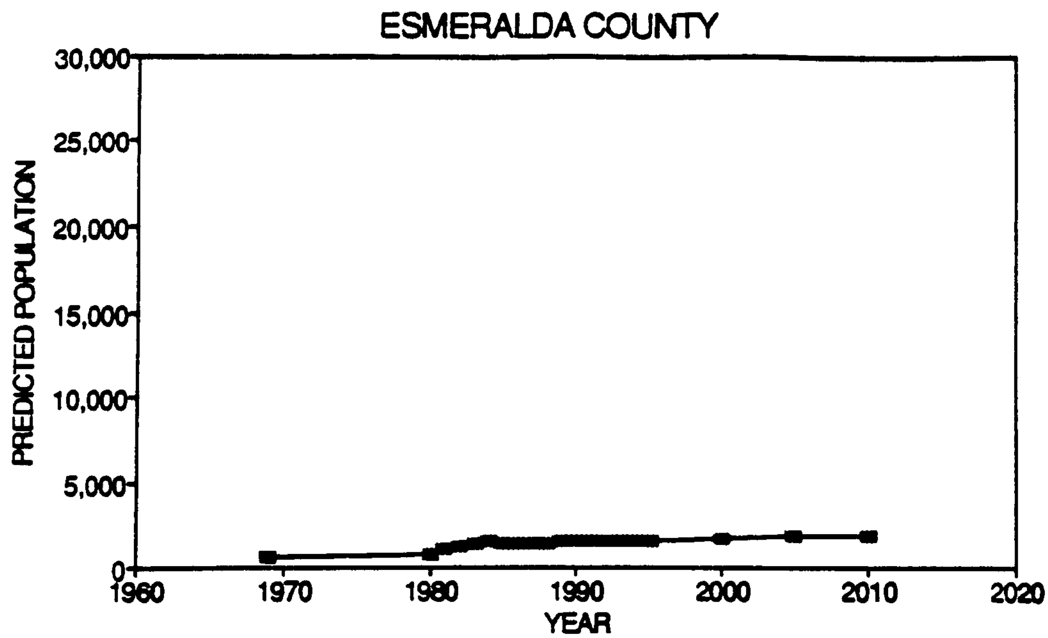


Figure 4c. Estimated Population Trends for Lincoln County

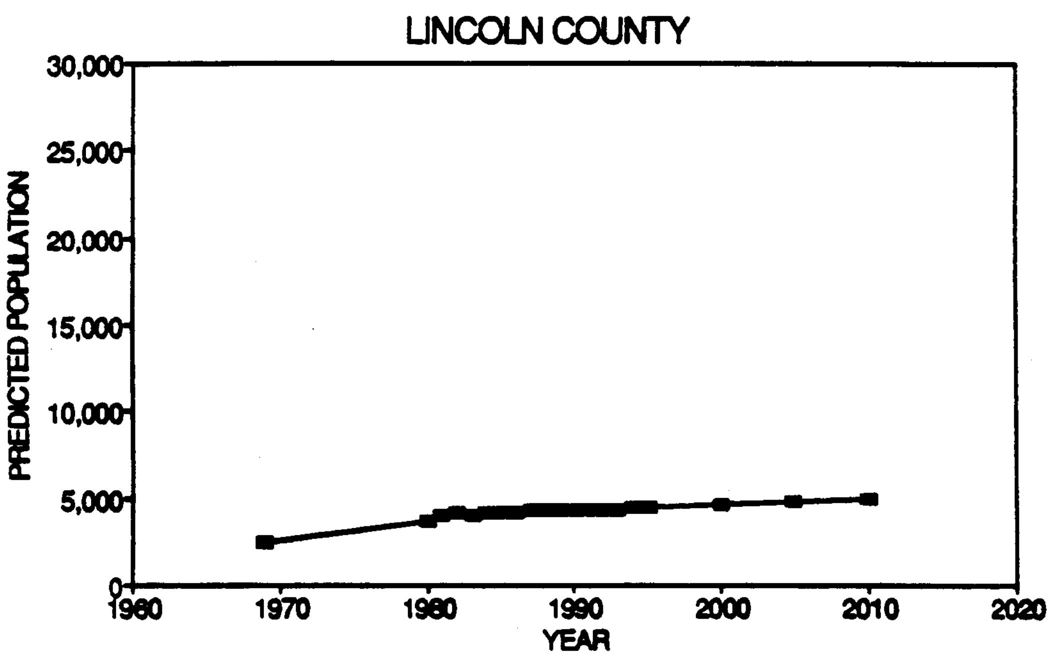
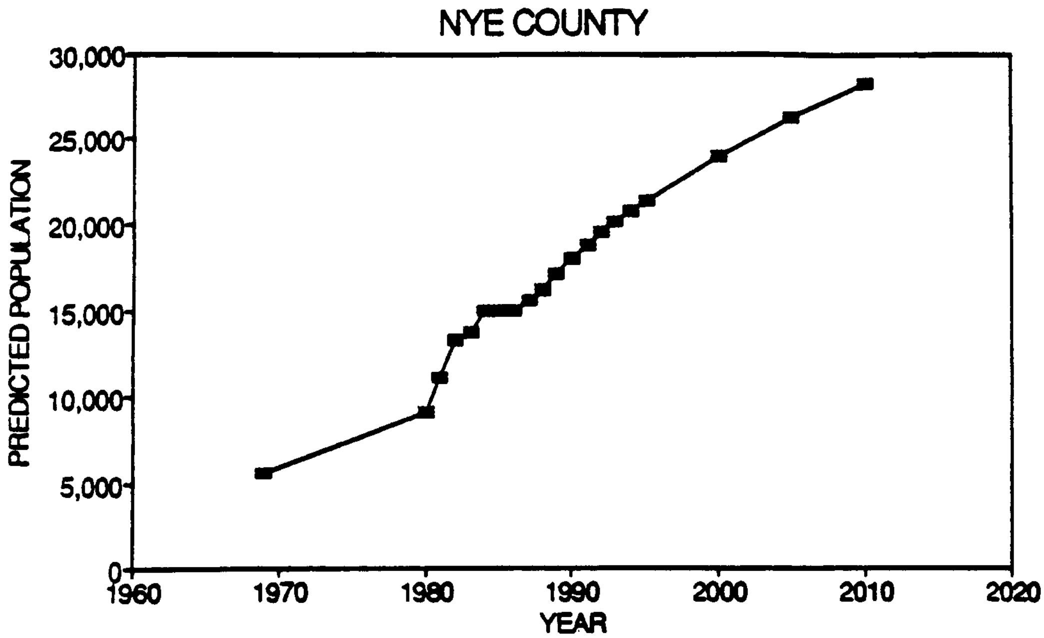


Figure 4d. Estimated Population Trends for Nye County



4.1 CURRENT WATER USAGE BY COUNTY

The most recent available (1985) water usage data are summarized in Figure 5. Surface and ground water demand for 1985 is given in Figure 6. Based on 1985 data, Table 2 gives water use per capita for each county. As shown in Table 2, the higher concentration of population (i.e., Clark County) produces a decrease in per capita consumption. The current economic expansion occurring in southern Nevada, specifically Clark and Nye counties, is based on light industrial/commercial development for which less water per capita is necessary. Arid agricultural regions such as Esmeralda and Lincoln counties require high per capita water demand, specifically for irrigation needs.

4.2 PROJECTED WATER DEMAND BY COUNTY

Figure 7 shows projected water usage (surface and groundwater) for Clark, Nye, Esmeralda, and Lincoln counties. The maximum available estimates delineated on Figure 7 are derived from perennial yields and the surface water assumptions discussed in Section 3.2;

groundwater resources in storage are not included. As can be seen from this figure, the only area anticipating significant water deficiencies in the future is Clark County. A breakdown of projected usage by county is given in Tables 6-9 and Figure 8.

Figure 5. Water Demands (1985) Based on Use

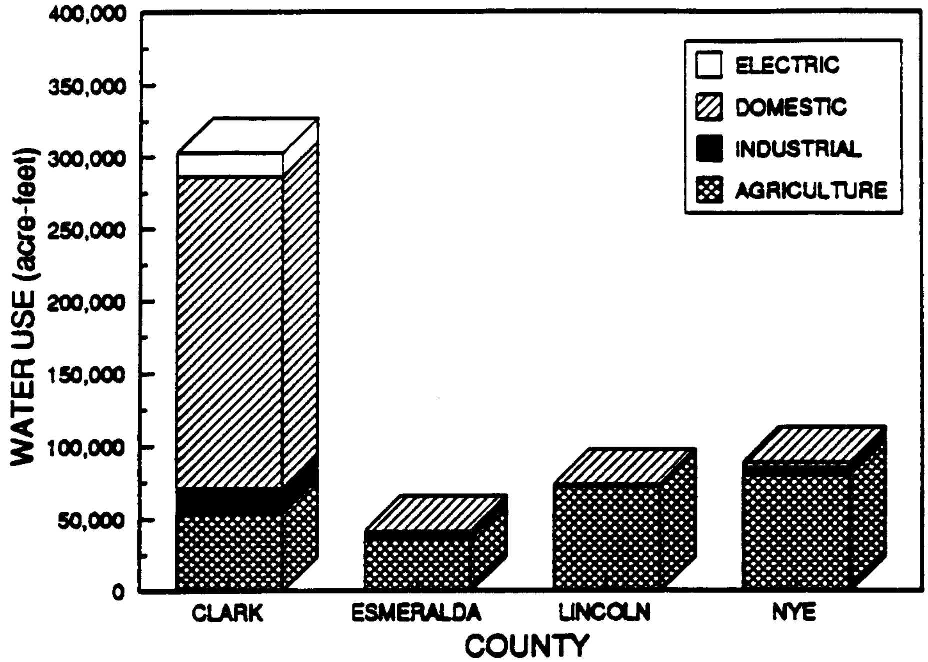


Figure 6. Water Demands (1985) By Source

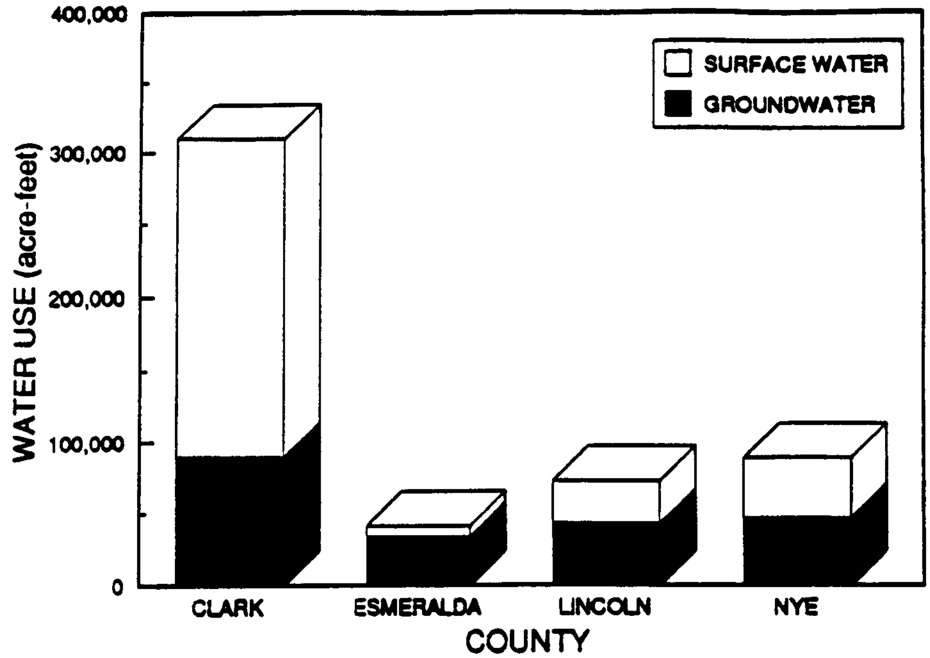


Figure 7a. Projected Water Demand - Clark County

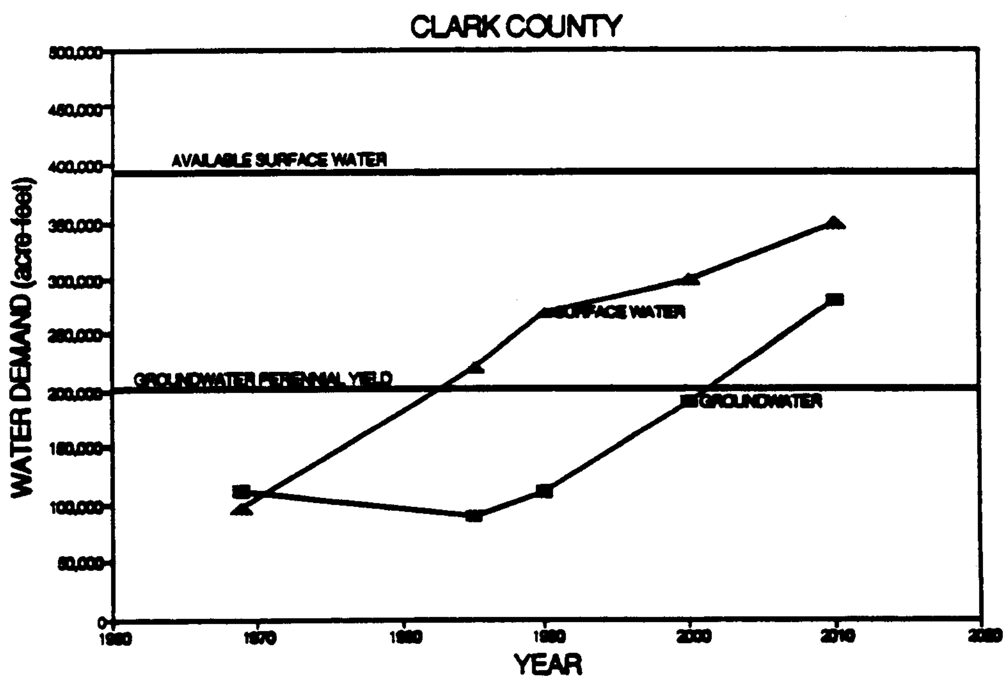


Figure 7b. Projected Water Demand - Esmeralda County

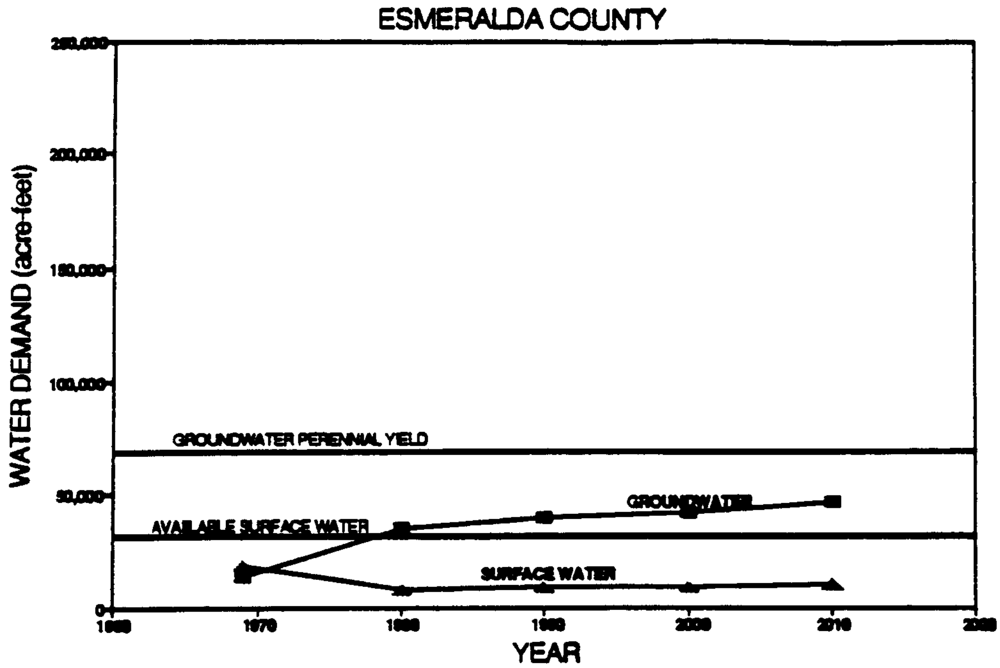


Figure 7c. Projected Water Demand - Lincoln County

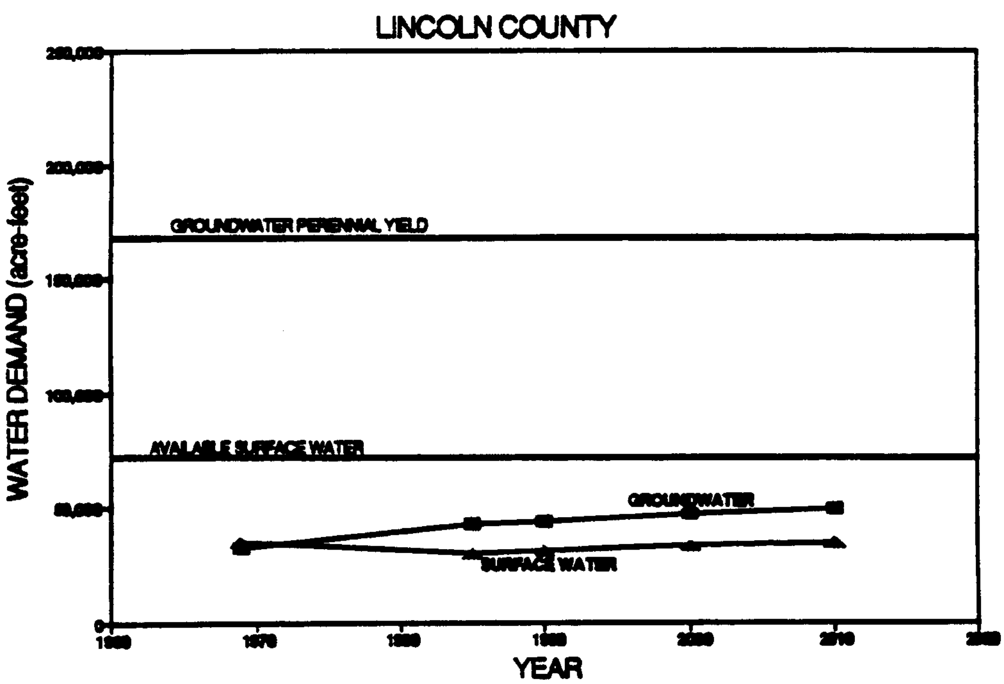
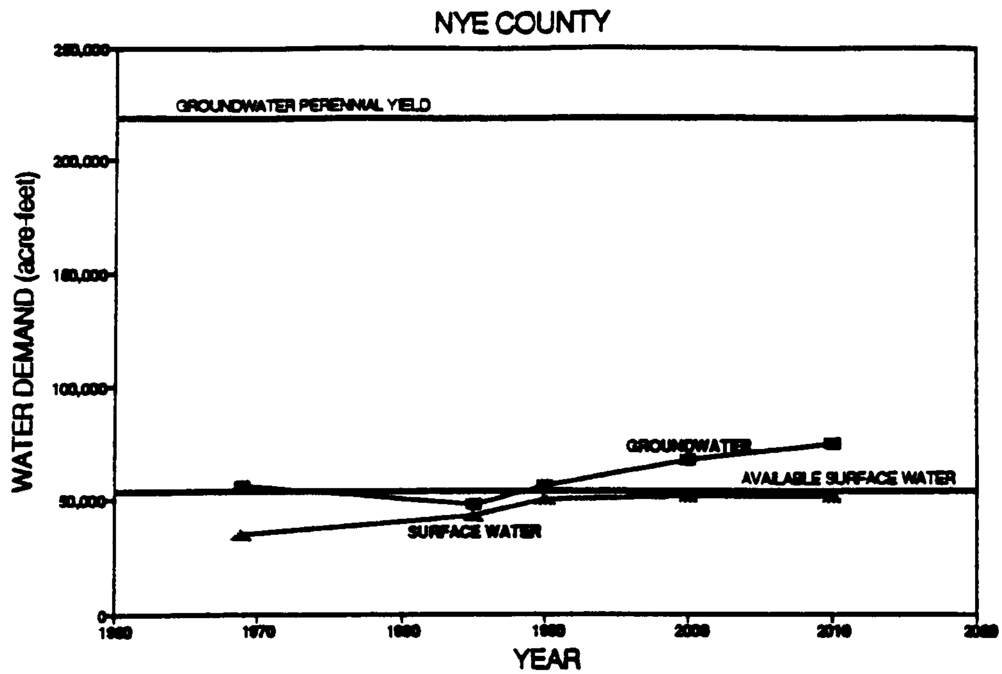


Figure 7d. Projected Water Demand - Nye County



Based on expected growth of industrial/commercial ventures in Clark and Nye counties, it is expected that limited agricultural expansion will take place. For projection purposes, irrigation needs are assumed to remain small with respect to population growth in Clark and Nye counties. However, based on the limited population growth in Lincoln and Esmeralda counties, it was assumed for projection estimates that agricultural expansion will continue in these counties. Domestic, industrial, and electric power water supply projections are directly dependent on the overall population growth of the region.

Table 6. Clark County Projections

YEAR	1969[6]	1985[7]	1990[8]	2000[7]	2010[7]
POPULATION	270,000	570,000	720,000	940,000	1,200,000
AGRICULTURE					
Wells	10,000	14,000	18,000	23,000	29,000
Streams & Springs	53,000	40,000	51,000	51,000	66,000
DOMESTIC					
Wells	82,000	55,000	69,000	120,000	200,000
Streams & Springs	19,000	160,000	200,000	230,000	260,000
COMMERCIAL, MINING AND INDUSTRIAL					
Wells	14,000	8,400	11,000	26,000	31,000
Streams & Springs	20,000	8,900	11,000	11,000	15,000
ELECTRIC POWER					
Wells	1,500	8,400	11,000	17,000	22,000
Streams & Springs	3,700	8,000	10,000	10,000	13,000
TOTAL WITHDRAWAL					
Wells	110,000	90,000	110,000	190,000	280,000
Streams & Springs	96,000	220,000	270,000	300,000	350,000

(all water demand data given in acre-feet)

[6] *Data from State of Nevada, 1971a.*

[7] *Data compiled by USGS, 1989 (unpublished, on file at ABC office and Nevada State Engineer's office)*

[8] *Projection by ABC, this report.*

Table 7. Esmeralda County Projections

YEAR	1969[5]	1985[6]	1990[7]	2000[7]	2010[7]
POPULATION	600	1,400	1,600	1,700	1,900
AGRICULTURE					
Wells	6,000	29,000	33,000	35,000	39,000
Streams & Springs	18,000	7,300	8,300	8,900	10,000
DOMESTIC					
Wells	80	240	240	240	240
Streams & Springs	25	0	0	0	0
COMMERCIAL, MINING AND INDUSTRIAL					
Wells	7,000	4,800	5,500	5,800	6,500
Streams & Springs	40	56	64	68	76
ELECTRIC POWER					
Wells	0	0	0	0	0
Streams & Springs	400	0	0	0	0
TOTAL WITHDRAWAL					
Wells	13,000	34,000	39,000	41,000	46,000
Streams & Springs	18,000	7,400	8,400	8,900	10,000

(all water demand data given in acre-feet)

Table 8. Lincoln County Projections

YEAR	1969[5]	1985[6]	1990[7]	2000[7]	2010[7]
POPULATION	2,500	4,200	4,300	4,600	4,900
AGRICULTURE					
Wells	30,000	42,000	43,000	46,000	49,000
Streams & Springs	35,000	30,000	31,000	33,000	35,000
DOMESTIC					
Wells	680	1,000	1,000	1,100	1,200
Streams & Springs	170	22	23	24	26
COMMERCIAL, MINING AND INDUSTRIAL					
Wells	1,000	240	240	240	240
Streams & Springs	0	0	0	0	0
ELECTRIC POWER					
Wells	0	0	0	0	0
Streams & Springs	0	0	0	0	0
TOTAL WITHDRAWAL					
Wells	32,000	43,000	44,000	47,000	50,000
Streams & Springs	35,000	30,000	31,000	33,000	35,000

(all water demand data given in acre-feet)

Table 9. Nye County Projections

YEAR	1969[5]	1985[6]	1990[7]	2000[7]	2010[7]
POPULATION	5,500	15,000	18,000	24,000	28,000
AGRICULTURE					
Wells	52,000	40,000	48,000	48,000	48,000
Streams & Springs	34,000	40,000	48,000	48,000	48,000
DOMESTIC					
Wells	970	3,400	4,100	5,400	6,300
Streams & Springs	320	90	110	140	170
COMMERCIAL, MINING AND INDUSTRIAL					
Wells	3,400	3,200	3,800	14,000	20,000
Streams & Springs	0	1,900	2,300	2,500	3,000
ELECTRIC POWER					
Wells	0	0	0	0	0
Streams & Springs	0	0	0	0	0
TOTAL WITHDRAWAL					
Wells	56,000	47,000	56,000	67,000	74,000
Streams & Springs	34,000	42,000	50,000	51,000	51,000

(all water demand data given in acre-feet)

Figure 8a. Projected Water Demands by Use - Clark County

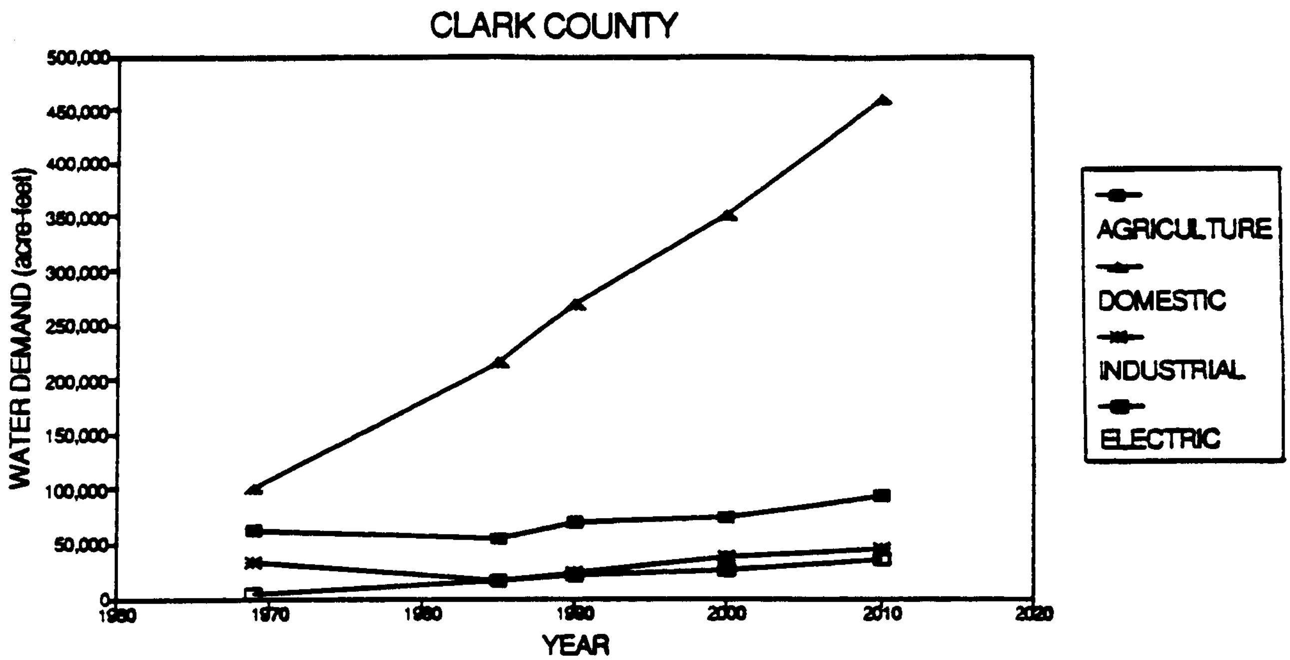


Figure 8b. Projected Water Demands by Use - Esmeralda County

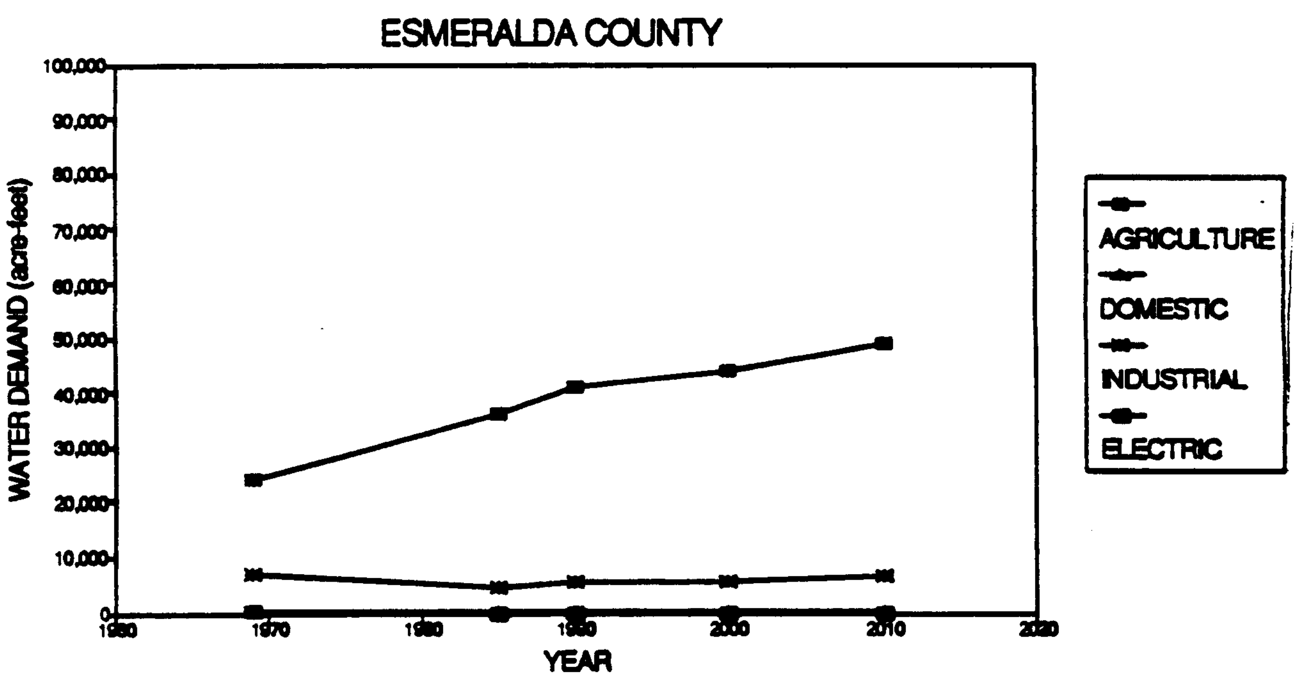


Figure 8c. Projected Water Demands by Use - Lincoln County

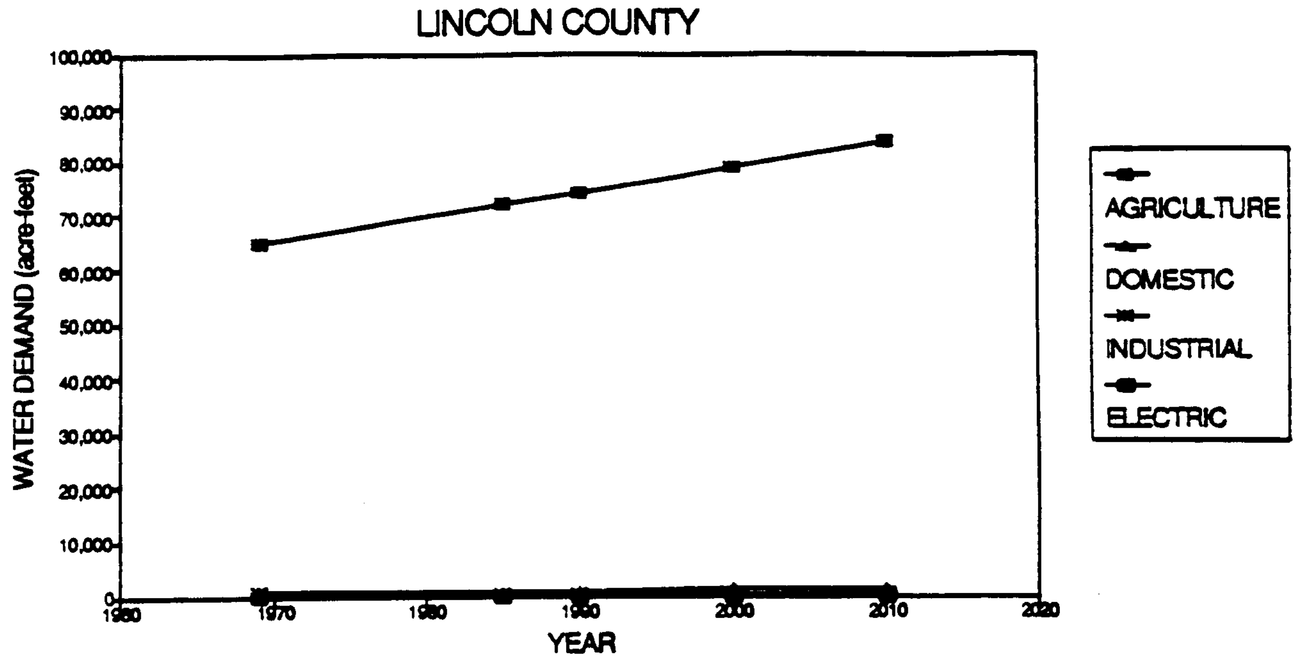
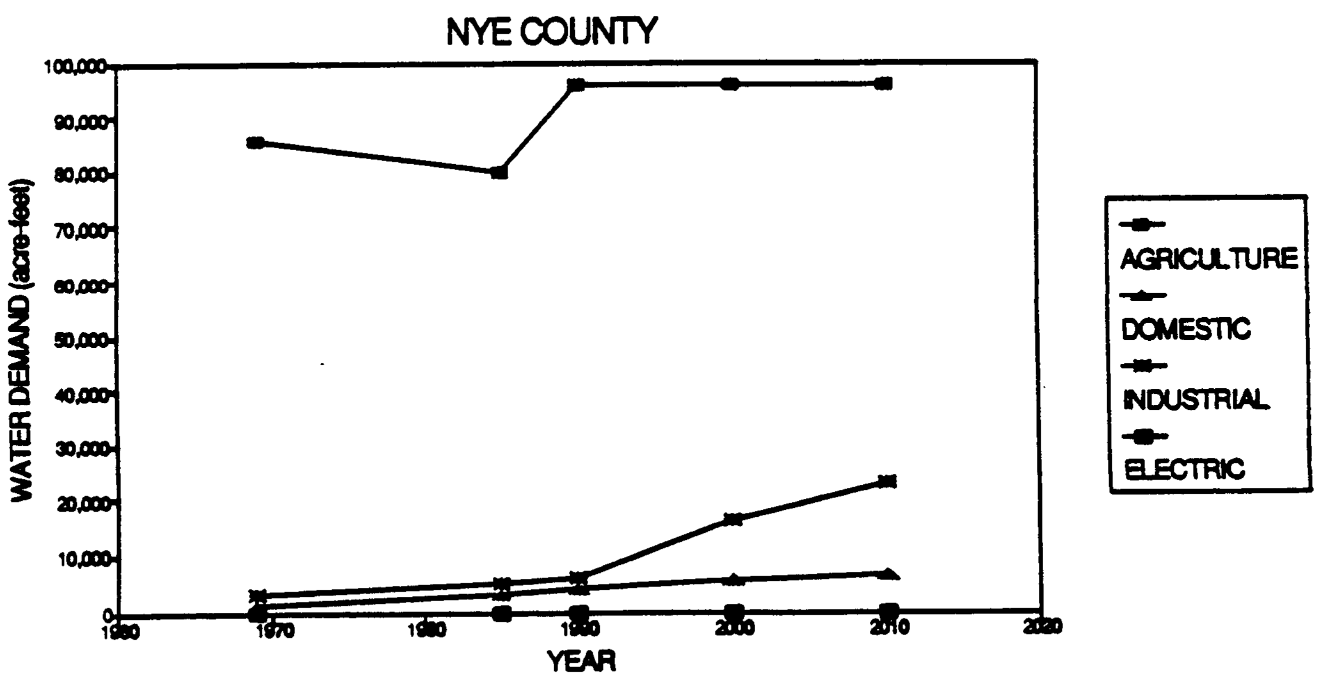


Figure 8d. Projected Water Demands by Use - Nye County



4.3 PROPOSED ALTERNATIVES TO WATER SUPPLY SHORTAGES

4.3.1 Alternative Water Policy

The present Nevada policy is based on the safe yield concept, as discussed in Section 3.1. The water supply limitations discussed above (i.e. designating basins, limiting groundwater mining as designated by the State Engineer (Section 3.1), etc.) are also based on this concept. If Nevada were to adopt an alternative policy, the water supply estimates for Las Vegas Valley (and other designated valleys) and the limitations predicted on the valley's water supply would change.

An alternative policy might be that of "optimal yield". An optimal yield policy is based on the premise that groundwater has value only by virtue of its use. Optimal yield must then be determined by selection of the best groundwater management program based on social and/or economic objectives (e.g., Domenico, 1972). In the case of arid lands such as southern Nevada, this could lead to more active mining of groundwater in storage - in some cases, even to complete depletion of water reserves in some basins.

Another alternative water policy might involve methods of better conservation. A water conservation program would promote a wiser use of Nevada's limited natural resource by reducing predicted potable water demands, investing in better wastewater management practices, and saving energy and, hence money, in requiring less pumping and heating costs. In the extreme, this policy would limit both water supply needs and economic growth. Extreme allocation of usage (e.g., no land irrigation permitted) and increased commodity costs (i.e., due to increased water costs) could slow the projected population and economic growth. Under a conservation policy, the previous water supply predictions and limitations would change drastically, potentially allowing the current water supply to last well into the next century.

4.3.2 Alternatives for Clark County Water Supply

The fastest growing counties in the state are Douglas, Clark, and Nye (in that order). Of the two southern counties, Clark County is the only county which anticipates a significant water supply deficit. If Clark County opts for water supply in other hydrographic basins, potential impacts (i.e. contamination or depletion) from development of an alternative water supply to the proposed high-level waste repository area must be considered.

At present, the Las Vegas metropolitan area has a net population gain of 3,000 - 4,000 people a month (Wallen, personal communication, 1989); the county population is expected to reach a million people by 2005. This influx puts a great deal of strain on the city's available water resources. The water purveyor of the metropolitan area (Las Vegas Valley Water District (LVVWD)) anticipates utilization of the full Colorado River allocation (300,000 acre-feet per year) by about 1993. As noted in Section 3.2, there are few other surface water resources available in Clark County. Hence, the future target is going to be retrieval of groundwater from various sources including groundwater resources outside the city and county. Considering just the water supply from the local (Las Vegas) alluvial aquifers, the long-term water supply outlook from Las Vegas Valley alluvium realistically is about 50,000 acre-feet per year (30,000 recharge + 20,000 return flow to the shallow aquifer) (State of Nevada, 1982). As shown in Figure 7a, more water will be necessary to supply the predicted demands.

Groundwater in the Las Vegas area has suffered from an overdraft since about 1960; problems including subsidence around Las Vegas have forced LVVWD to consider mitigating alternatives to mining groundwater in the highly populated areas (State of Nevada, 1982). LVVWD is also concerned with supplying enough water to meet the area's anticipated growth. To alleviate the overwithdrawal of groundwater in the Las Vegas Valley Basin, permit applications have recently been submitted to the State Engineer for approximately 500,000 acre-feet per year of groundwater to be drawn from valleys north of Las Vegas in Clark, Lincoln, and Nye counties (Wallen, personal communication, 1989). Other alternatives which have been considered include importation of groundwater from other adjacent valleys, interstate water importation, exploration for and development of a deep carbonate aquifer below the valley-fill in Las Vegas Valley, and water banking of natural recharge or Colorado River water by storage in the principal aquifers.

Of these alternatives, the only alternative which could have a direct impact concerning the proposed HLWR would be that of mining groundwater from valleys adjacent to the HLWR site. Of the valleys studied, four valleys had the potential for supplying the needs of Las Vegas for about 35 years (State of Nevada, 1982). These valleys include Amargosa Desert Valley, Pahrump Valley, Railroad Valley, and Pahranagat Valley (Figure 9). According to State of Nevada (1982), the water was considered of acceptable quality except for the high fluoride concentration in the Amargosa Desert (which would require treatment). The quantities available from pumping an alternative primary valley fill aquifer (to include mining all the water in the upper 100 feet of saturated valley-fill) would supply Clark County over a 26 to 50 year span with slightly more than 100,000 acre-feet of water per year. Table 10 summarizes water availability in these valleys.

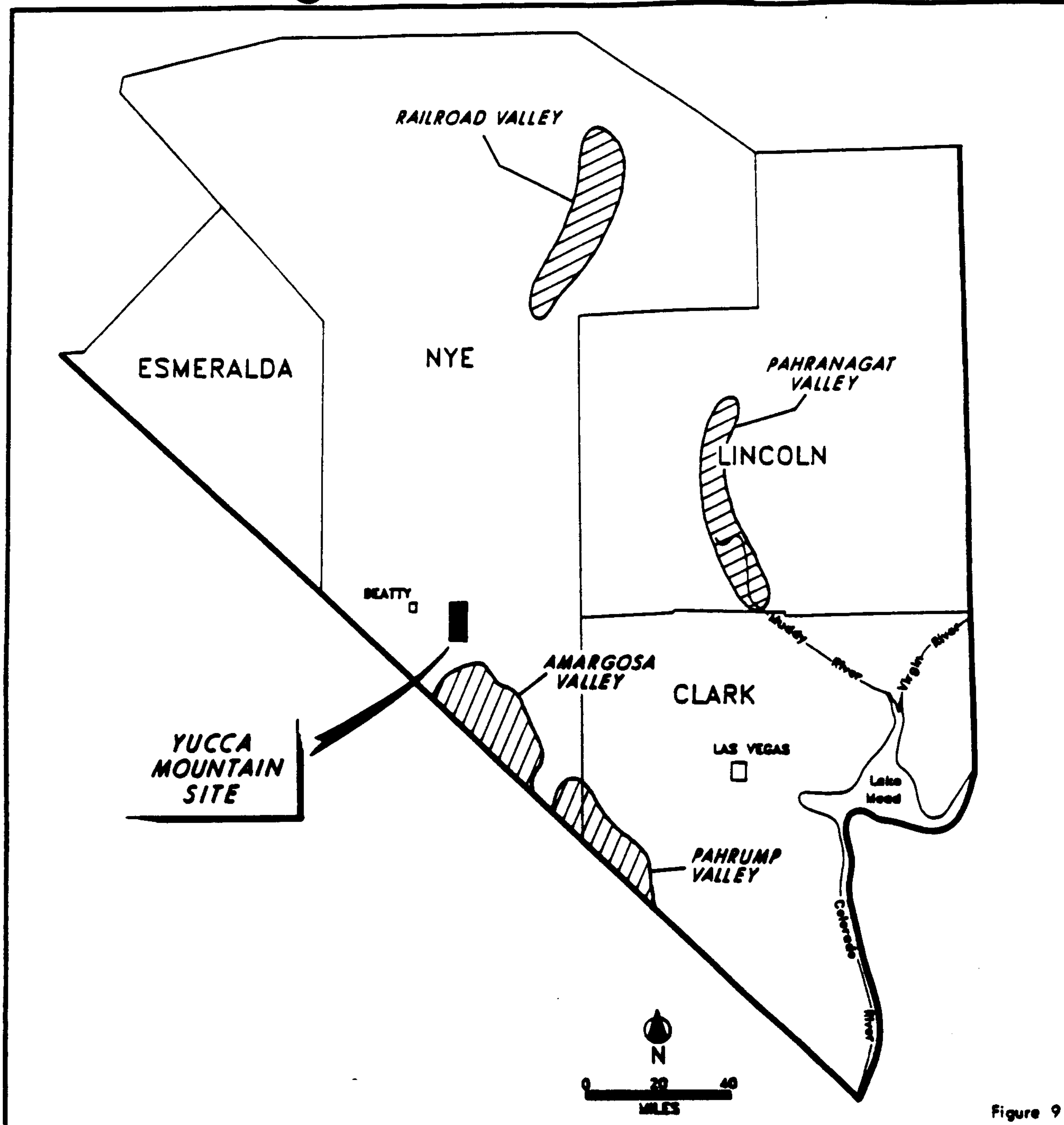


Figure 9

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CLARK COUNTY
ALTERNATIVE SUPPLY
SOURCES

Table 10. Available Water in Selected Valleys

Area of Import	Years	AF/Year	Water in Storage Upper 100 feet (Acre-feet)	Perennial Yield (AF/Year)
Pahrump Valley	33	127,500	4,200,000	12,000
Amargosa Desert	27	110,000	2,970,000	24,000
Railroad Valley	50	156,000	7,800,000	52,000
Pahranagat Valley	26	110,000	2,870,000	25,000

Table 11 summarizes estimated project costs for development of the alternative water supply sources (State of Nevada, 1982). These costs are corrected to 1990 dollars (Appendix A) using a five percent inflation rate since 1980 and an interest rate over the expected useful project life of nine percent. Typical 1982 water costs for public supply users in southern Nevada was about $50/acre-ft (State of Nevada, 1982). The State's assessment in 1971 was that the needs of Las Vegas Valley could justify expenditures of up to $230/acre-ft (1970 prices). If we were to assume a five percent inflation rate on the 1970 price, a cost of $610/acre-ft would be justifiable today. The importation costs given in Table 11 are about twice as much as today's justifiable investment. Nevada's present water supply and economic system does not merit intrastate importation of water.

Table 11. Importation Costs for Selected Valleys*

Area of Import	Project Life (yrs)	Ann. Capital Cost (millions)	Ann. Oper. Cost (millions)	Unit Cost of Water $/ac-ft
Pahrump Valley	33	$ 90.0	$26.7	$ 915
Amargosa Desert	27	$116.4	$26.4	$1,298
Railroad Valley	50	$171.1	$23.2	$1,246
Pahranagat Valley	26	$ 98.1	$12.2	$1,003

* All costs are based on 1990 prices.

Aside from the high costs, further constraints on use of the water from these valleys exist due to the Protected Wetlands and the Endangered Species Act which lists fish sanctuaries in Pahranagat Valley, Railroad Valley and in Ash Meadows (Amargosa Desert). Exploitation could dry up many of the habitat springs and surface waters.

5.0 SUMMARY AND CONCLUSIONS

Although careful water-use planning is imperative as a matter of policy for the arid climate of southern Nevada, review of the water resources available support the claim that, under current conditions, water shortages are not expected except in the highly populated Las Vegas Valley area. Abundant one-time water supply is available from groundwater in storage (i.e., usually in alluvium) and also perhaps in the deep carbonate aquifers, however, present economic conditions and current water policy do not merit development of these water resources.

Water supply alternatives for Clark County which could be directly related to the proposed high-level waste repository (HLWR) in Nye County are discussed in Section 4.3 of this report. Under certain extreme assumptions, development of water supply sources in the vicinity of Yucca Mountain could change the groundwater flow system, which could affect long-term waste isolation of the HLWR.

As discussed in Section 2.0, the natural-resource evaluations of Part 60 are concerned with two issues: (1) impacts which may affect compliance with NEPA (i.e., effects from the HLWR on the natural (or human) environment) and (2) impacts of human activities which may influence compliance with the performance standards of 10 CFR Part 60 (i.e., effects on the HLWR by natural resource exploitation). Both of these issues are of concern when considering groundwater exploitation and the resulting impacts from or on the proposed repository. Will the groundwater be safe for its intended use, based on HLWR impacts, and will exploitation of groundwater change the performance of a HLWR? A policy of extreme conservation would lead to no expected impacts (e.g., depletion of water resources, changes in groundwater flow system) and little growth in the State. The present safe-yield policy will limit growth and would lead to a small probability of adversely affecting the HLWR. Extreme exploitation of groundwater in the region would have the greatest potential for impact from the HLWR, although the HLWR design is such that groundwater contamination should be unlikely, based on the concepts of 10 CFR Part 60.

Possible impacts on performance of the HLWR could occur if the saturated zone within the controlled area contained a high concentration of radionuclides from the repository and if extensive pumping outside the controlled area caused a change in lateral hydraulic gradient which could expedite contaminant transport and provide a pathway (human consumption) that would endanger human health and safety. The probability of this occurring in the vicinity of Yucca Mountain is discussed in the third report of this series - A Methodology for Assessing Ground Water Resources as a Potential Source of Human Intrusion (1989). Based on current water policy, water supply, predicted water demands, and the proposed

HLWR design, there is a small likelihood of impact to performance of a HLWR at Yucca Mountain. Projected water supply needs and economic necessity are not anticipated to be so extreme as to instill the need to exploit all groundwater resources in southern Nevada to such a degree as to effect the general groundwater flow system in the vicinity of Yucca Mountain.

The projections given in this report face all the same uncertainties involved in any resource and economic planning. At present, Nevada economists have projected population growth to the year 2010 with probably reasonable accuracy. Predictions with respect to water planning past the 20-year span are regarded with a higher degree of uncertainty. However, population growth will eventually be controlled by water (and other natural-resource) supply constraints, as has been known since at least the time of Thomas Malthus (1798). Thus, population will not continue to increase at current rates for any extended period of time, as even at $900-$1,300 per acre-foot (Table 11), the exploitation of the four valleys is capable of producing only 100,000-150,000 acre-feet/year for only about 140 years. This is only a 35% increment on current water resources, which increment would be exhausted (and its potential hydrologic impact on the HLWR maximized) well within the containment period of 300-1,000 years (10 CFR Part 60.113(a)). However, if extensive groundwater mining of the western valleys is pursued in the future, its impact (if any, see ABC, 1989)) on the HLWR system could persist significantly into the repository lifetime due to the expected low recharge rates and would need further consideration.

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APPENDIX A
SAMPLE CALCULATIONS FOR 1990 COST ESTIMATES

The following is a set of sample calculations used to convert the State's 1980 project cost estimates (State of Nevada, 1982) for Clark County alternative water supply sources to current 1990 costs as was discussed in Section 4.3 of this report. A five percent inflation rate and an interest rate of nine percent is assumed.

Given that Pahrump Valley was estimated to have a useful project life of 33 years, an average water delivery of 127,500 acre-feet per year, an initial capital cost of $578,175,000 (1980 dollars), and an annual operating cost of $16,384,000 (1980 dollars), conversion to today's costs are as follows.

Convert initial capital cost and annual operating cost estimates to 1990 prices:

$$IC_{90} = IC_{80}\ (1+i)^{n}$$

and $$AOC_{90} = AOC_{80}\ (1+i)^{n}$$

where:
- IC_{90} = initial capital cost in 1990 dollars
- IC_{80} = initial capital cost in 1980 dollars
- i = annual rate of inflation (0.05)
- n = years difference between 1990 and 1980 (10)
- AOC_{90} = annual operating cost in 1990 dollars
- AOC_{80} = initial capital cost in 1980 dollars

$$IC_{90} = \$578,175,000\ (1+0.05)^{10} = \$942 \text{ million}$$

and $$AOC_{90} = \$16,384,000\ (1+0.05)^{10} = \$26.7 \text{ million}$$

The initial capital cost is amortized over the estimated project life (e.g., 33 years) by the following calculation:

$$ACC = IC_{90}\ (t(1+t)^{PL})/((1+t)^{PL} - 1)$$

where: ACC = annual capital cost
PL = project life (33 years)
t = annual interest rate (0.09)

$$ACC = \$942 \text{ million } ((0.09)(1+0.09)^{33})/((1+0.09)^{33} - 1)$$
$$= \$90.0 \text{ million}$$

Finally, the unit cost for water is calculated using the total estimated annual project cost (annual capital cost + annual operating cost) divided by the estimated water transported per year.

$$\text{Unit Cost} = (ACC + AOC_{90})/\text{yearly water transported}$$

$$\text{Unit Cost} = \frac{(\$90.0 \text{ million} + \$26.7 \text{ million})}{127{,}500 \text{ acre-feet per year}}$$

Unit Cost of Water = \$915/acre-ft