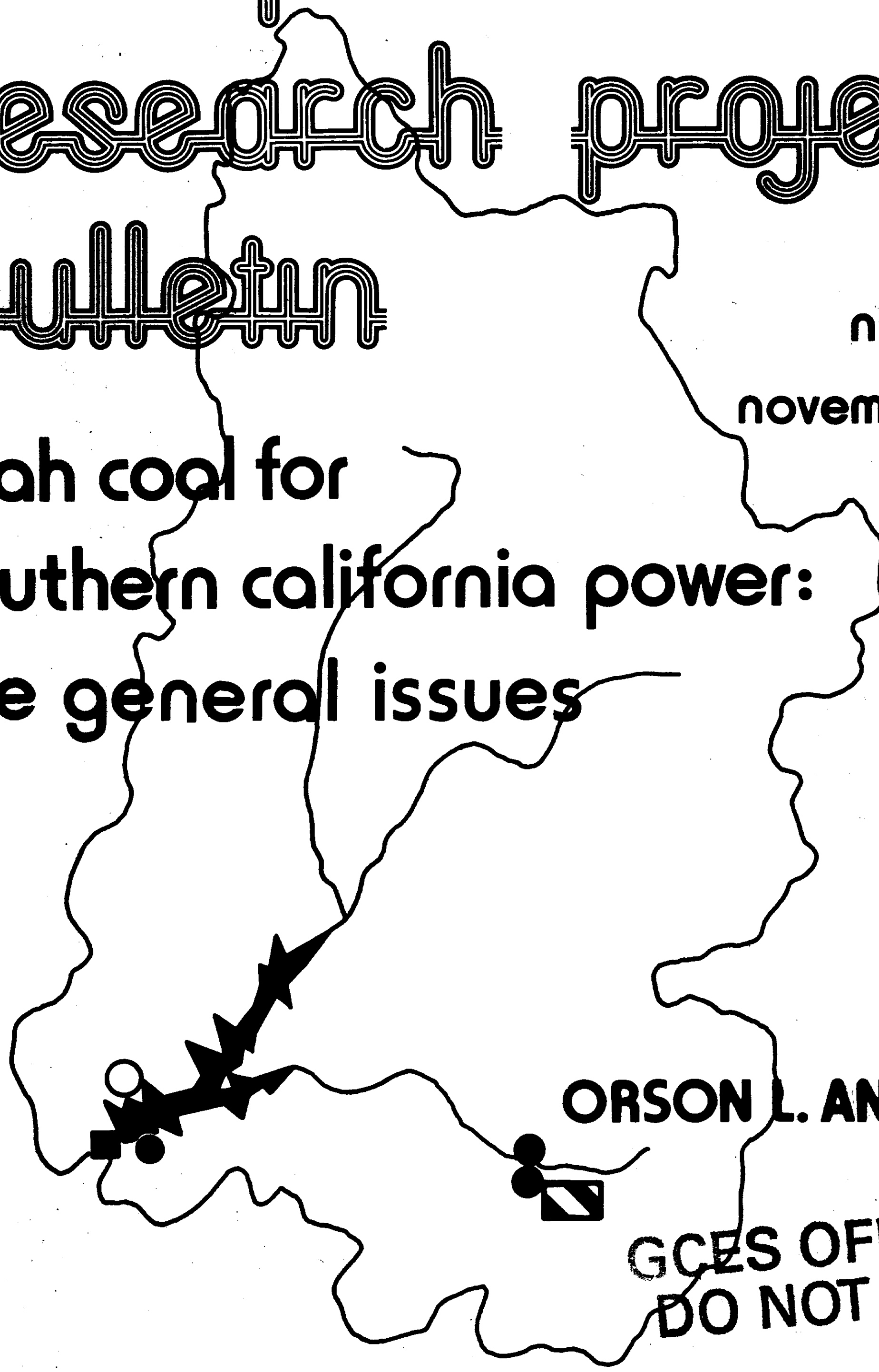
lake powell research project bulletin

number 13
november 1975



utah coal for southern california power: the general issues

ORSON L. ANDERSON

National Science Foundation
Research Applied to National Needs

ECQ413

LAKE POWELL RESEARCH PROJECT BULLETIN

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a publication of the research project

COLLABORATIVE RESEARCH ON ASSESSMENT OF MAN'S ACTIVITIES
IN THE LAKE POWELL REGION

funded by

Research Applied to National Needs
National Science Foundation

Funded Institutions

Dartmouth College
John Muir Institute
Northern Arizona Society of Science and Art, Inc.
University of Arizona
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University of California, Santa Barbara
University of New Mexico
University of Rochester
Utah State University

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Price: $2.50, Payable to the Regents of the University of California

UTAH COAL FOR SOUTHERN CALIFORNIA POWER: THE GENERAL ISSUES

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Los Angeles, California 90024

November 1975

LAKE POWELL RESEARCH PROJECT

The Lake Powell Research Project (formally known as Collaborative Research on Assessment of Man's Activities in the Lake Powell Region) is a consortium of university groups funded by the Division of Advanced Environmental Research and Technology in RANN (Research Applied to National Needs) in the National Science Foundation.

Researchers in the consortium bring a wide range of expertise in natural and social sciences to bear on the general problem of the effects and ramifications of water resource management in the Lake Powell region. The region currently is experiencing converging demands for water and energy resource development, preservation of nationally unique scenic features, expansion of recreation facilities, and economic growth and modernization in previously isolated rural areas.

The Project comprises interdisciplinary studies centered on the following topics: (1) level and distribution of income and wealth generated by resources development; (2) institutional framework for environmental assessment and planning; (3) institutional decision-making and resource allocation; (4) implications for federal Indian policies of accelerated economic development of the Navajo Indian Reservation; (5) impact of development on demographic structure; (6) consumptive water use in the Upper Colorado River Basin; (7) prediction of future significant changes in the Lake Powell ecosystem; (8) recreational carrying capacity and utilization of the Glen Canyon National Recreational Area; (9) impact of energy development around Lake Powell; and (10) consequences of variability in the lake level of Lake Powell.

One of the major missions of RANN projects is to communicate research results directly to user groups of the region, which include government agencies, Native American Tribes, legislative bodies, and interested civic groups. The Lake Powell Research Project Bulletins are intended to make timely research results readily accessible to user Groups. The Bulletins supplement technical articles published by Project members in scholarly journals.

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ABSTRACT

For the next decade, Southern California is committed to receiving a large part of its electrical energy from coal-fired powerplants located outside California. This dependence on coal arises from arrangements made by the electrical utilities of Southern California with officials of the Federal government and of states other than California. Of particular importance is the planned construction of two 3,000-megawatt mine-mouth coal-fired electrical powerplants in Utah, from which the majority of electrical power produced would flow to Southern California.

The establishment of coal-fired powerplants sited outside the State of California for the benefit of Southern California residents raises a number of problems which are not entirely resolved. The solution of these problems is deemed important, not only because they determine the fulfillment of the existing plans for the next decade, but also because planners must allow for the possibility that California may need further major energy development based upon Utah coal in the decades beyond 1985.

There are many issues to be considered, but they can be reduced to four major classes: (1) those arising from the use of Upper Colorado River Basin surface water in the production of energy, (2) those arising from the degradation of air quality in the area where the plants are sited, (3) those arising from the choices for the mode of transportation of the energy from the producer region to the consumer region, and (4) those arising from the socioeconomic impact on the producer region.

The issues are interrelated in a complex way. At the present time, the powerplants are sited in Utah, which means that (1) Utah's surface water must be used for power production, (2) the air quality of Utah's recreational areas (including outstanding National Parks and Monuments) will be degraded, and (3) energy will flow by electrical transmission lines to California. Many alternate combinations exist, and several are considered in this Bulletin. For example, the air quality and water resources problems would be quite different if the powerplants using Utah coal were located in California.

Research tasks which could provide information for addressing these issues are identified, and appropriate recommendations are made.

UTAH COAL FOR SOUTHERN CALIFORNIA POWER: THE GENERAL ISSUES

INTRODUCTION

Forecasts of California's Energy Demands

Well before the Arab oil embargo, which clearly focused public attention on the energy crisis, the Resources Agency of the State of California issued a booklet entitled Energy Dilemma.[1] This booklet emphasized the future power problems California will have as a result of her dependence on petroleum and natural gas. The Arab oil embargo, which resulted in more than a fourfold increase of the cost of oil, merely intensified most of the issues previously recognized by the Resources Agency.

Energy Dilemma indicated that the declining availability of gas would force California electric utilities to substitute oil for gas as the major fuel. Difficulties in obtaining low-sulfur oil to satisfy air quality regulations would induce the utilities to rely increasingly on nuclear power in the future. The vulnerability of the nation's economy to dependence on large foreign oil importations was discussed. The State's planners felt in 1973 that coal, as a fuel for electric power, would be a minor component in California's energy future. Most of the anticipated coal-fired powerplants would serve Southern California utilities,[2] so the proportion of coal in the energy mix of Southern California would be larger than in the State as a whole.

The basic energy markets of California in 1970 are shown in Figure 1. Oil was the major source of the California energy supply, and coal was a minor component.[3] Figure 2 shows the Resources Agency forecast for 1985 (made early in 1973) for the energy supplies for California.[4] It is to be noted that in 1973, the State Resources Agency of California expected that the importation of oil from outside California would increase by about a factor of seven (47 percent of 5,187,000 bbl, versus 13 percent of 2,639,000 bbl) between 1970 and 1985. This is a good example of the optimistic assumptions of the availability of foreign oil that were made in energy planning prior to the Arab embargo. Few forecasts made recently, whether national or regional, assume that imported foreign oil will become such a large factor either in the nation's or in California's energy mix. Some increase is predicted in the use of oil (domestic and foreign combined) imported from outside the State, but not an increase by a factor of seven.

The Resources Agency expected California's production of oil to drop by nearly one-half between 1970 and 1985 (36 percent of 2,639,000 bbl versus 10 percent of 5,187,000 bbl). Meanwhile, nuclear power capabilities were expected to increase manyfold. Coal and geothermal energy sources were considered as only minor elements in the California energy supply (Figures 1 and 2).

Since the energy crisis of late 1973 and 1974, forecasts for future energy supplies for California utilities have changed markedly. The California Public Utilities Commission issued a 10- and 20-year forecast in late 1974, which indicated the much greater dependence of California (and in particular, Southern California's utilities) on coal in the future.[5] A compilation made from data in Table 1 of the Commission's report forecasts that by

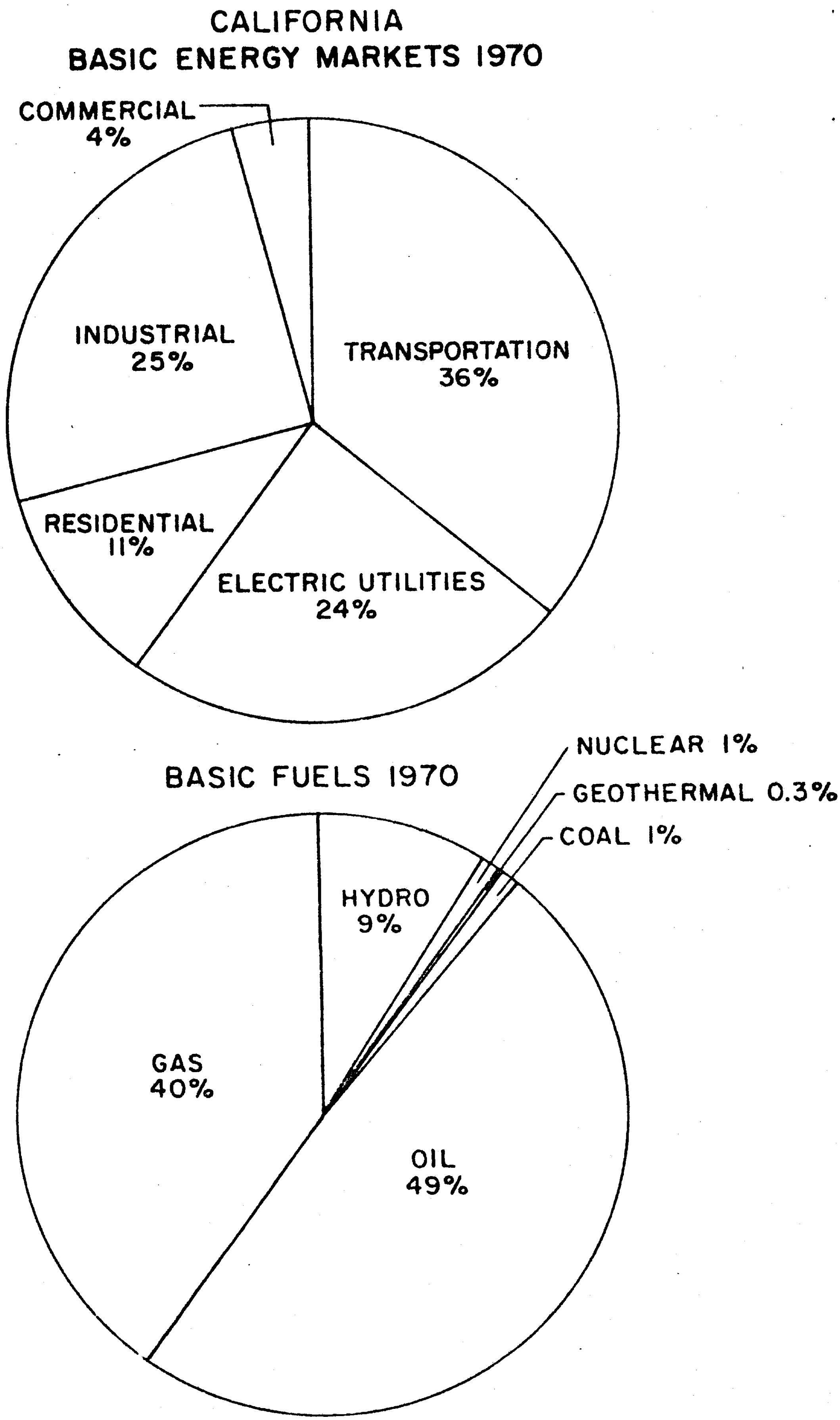


Figure 1: California Basic Energy Markets and Fuels, 1970
(Source: Reference 3, page 5)

CALIFORNIA
BASIC ENERGY SUPPLIES

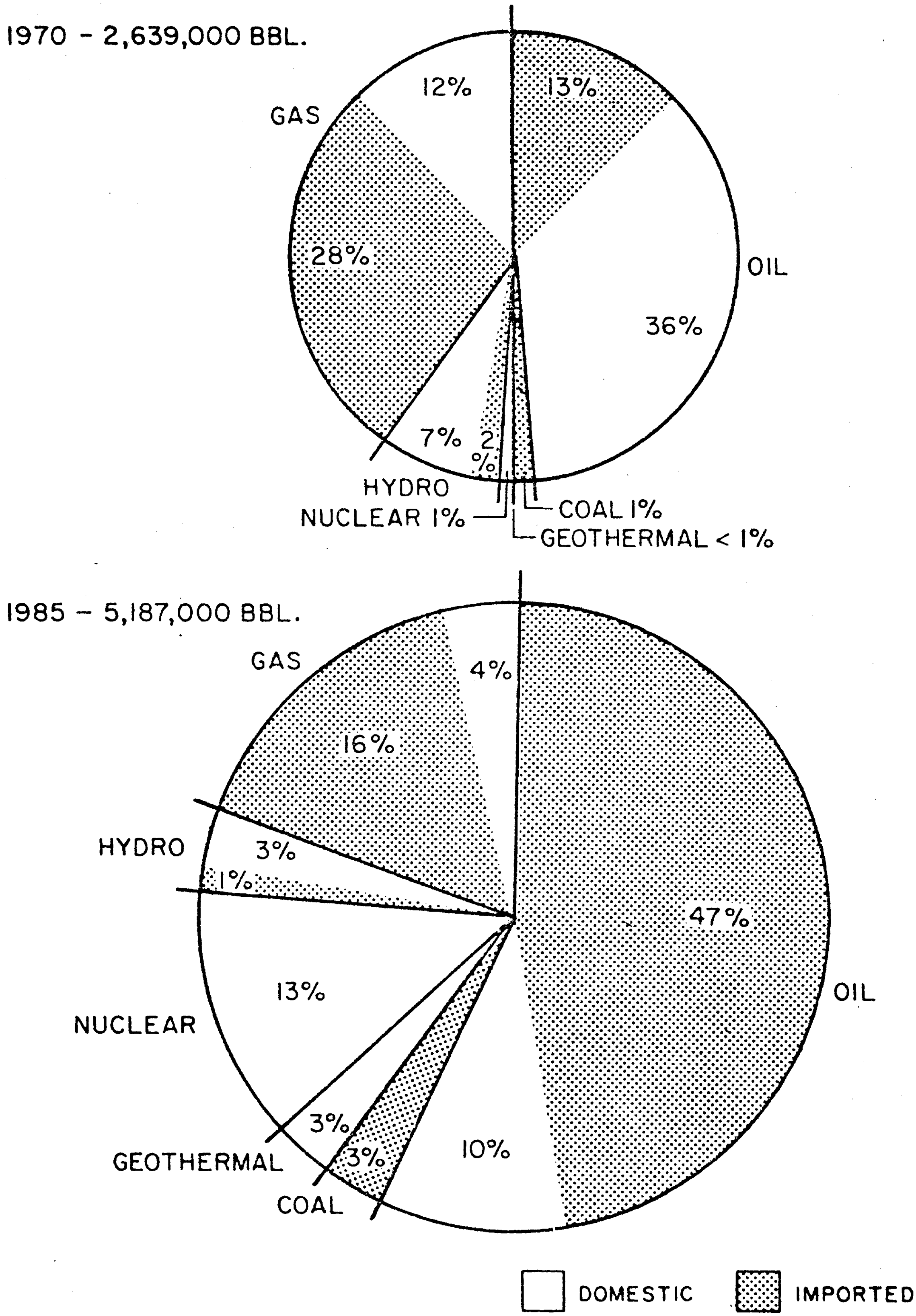


Figure 2: California Basic Energy Supplies, 1970 and 1985
(Source: Reference 3, page 51)

1984 25.6 percent of Southern California's electrical energy will be fired by coal. (This amount is 9.7 percent of the expected electrical energy for the State.) According to the data in the Commission's report, about 40 percent of the increase in Southern California's generating capacity in the period 1974-1984 will come from coal-fired powerplants.

Another way of considering these data in the Commission's report is to note that power facilities fired by fossil fuels other than coal were forecast to be 32.5 percent of the increased electrical generating capacity (to be constructed) of California in the period 1974-1984.

According to present plans, one Southern California utility will be especially dependent on new coal-fired plants. The Department of Water and Power (LADWP) expects to receive at least 24.5 percent of its energy from coal-fired plants by 1984. Coal is forecast to be more important than nuclear energy for both San Diego Gas & Electric (SDG&E) and Southern California Edison (SCE) in 1984. The data for these percentages are shown in detail in Table 1.

Thus, in 2 years, the forecasts of California energy sources have dramatically changed. Coal, once predicted to be of minor consequence for Southern California utilities, is now regarded as of major importance.

Distribution of California's Energy Demand

The energy market of California departs from the national average in at least two respects. The transportation sector consumes relatively more energy in California than in the rest of the nation. Conversely, the commercial and residential sectors consume less (Table 2 and Figure 3).

Transportation costs are higher for Californians because of the large dependence on the automobile, a phenomenon some call the "car culture." Costs in the residential and commercial markets are lower for Californians because favorable climatic conditions lessen demand. The relative energy requirements for space-heating in the United States are shown in Figure 4, which indicates that the energy cost for heating to residents of Minnesota is three to five times more than that for residents of California. From Figure 4 it is also seen that the relative space-heating costs are less in Southern California than in the State as a whole.

Distribution of Energy Demand for California Utilities

Table 2 shows that the relative costs to California for electric utilities are about the same as they are for the United States. Moreover, the projections for the future of the electrical utilities are about the same for California as for the nation (Table 3).

The forecasts made in 1973 by the State Resources Agency for California utilities for energy supplies in 1985 are shown in Figure 5. By that time it was expected that most of the energy would be provided by oil and nuclear sources. Now it is thought that coal will provide a greater share of the energy supply of Southern California electric utilities in 1985 (Table 1).

As an example of the increased role of coal in supplying utilities, the forecast for national energy supplies in 1985 made by Edward Teller[11] is: nuclear, 12 percent; coal, 33 percent; hydro, 3 percent; gas and oil, including conventional, shale,

Table 1: Coal in Southern California's Future

Major California Utilities: Projected Dependence on Coal and Nuclear Plants

Utility	1974 % coal	1984 % coal	1974 % nuclear	1984 % nuclear
LADWP	9.0	23.3	0	7.6
SCE	12.2	14.2	2.6	12.6
SDGE	0	18.3	3.8	13.7
PGE	0	4.4	0.9	28.0

LADWP: Los Angeles Department of Water and Power
SCE: Southern California Edison
SDGE: San Diego Gas & Electric
PGE: Pacific Gas & Electric

Colorado River Basin Coals as Southern California Energy Sources
Capacity in Megawatts for 1984 (projected)

	LADWP		SCE		SDGE
Mohave	296	Mohave	884.8		
Navajo	550	Four Corners	690.0		
IPP	1,500	Kaiparowits	1,164.0	Kaiparowits	702
TOTAL	2,346		2,738.8		702

Mohave and Navajo: Black Mesa coal, Navajo Reservation, Arizona
Four Corners: San Juan Basin coal, New Mexico
IPP and Kaiparowits: proposed for southern Utah, Utah coal
IPP: Intermountain Power Project

Total Projected Capacity in 1984: Megawatts (coal-fired and other sources)

	LADWP	SCE	SDGE
total load MW	6,856	18,258.4*	3,829
coal fraction	23.3%	14.2%	18.3%

*Total Installed Resources MW

Data for Computation of Nuclear Percentages for SDGE

1974 Nuclear Fired Plants	Capacity MW	1974 Total Load, MW	1984 Nuclear Fired Plants	Capacity MW	1974 Total Load, MW
San Onofre	86	2,214	San Onofre	526	3,829

Sources: Reference 5, Table 1; Reference 1, Table 7; Reference 6; F. A. McCrackin, Southern California Edison, personal communication 1975; H. Christie, LADWP, personal communication 1975; B. W. Shackelford, PGE, personal communication 1975; Jack E. Thomas, SDGE, personal communication 1975.

Table 2: Comparison of National and Californian Energy Demand by Sector

	Electric Utilities	Transportation	Industrial	Residential and Commercial
U.S. Energy Demand (1973)*	26%	24%	24%	30%
California Energy Demand (1970)**	24%	36%	25%	15%

*Source: Reference 8.
**Source: Reference 1, page 18.

Table 3: Percent Demand for Electric Utilities for California and the United States

	1970	1975	1985
California*	24%		32%
United States**		26%	

*Source: Reference 3, page 13.
**Source: Reference 8, page 15.

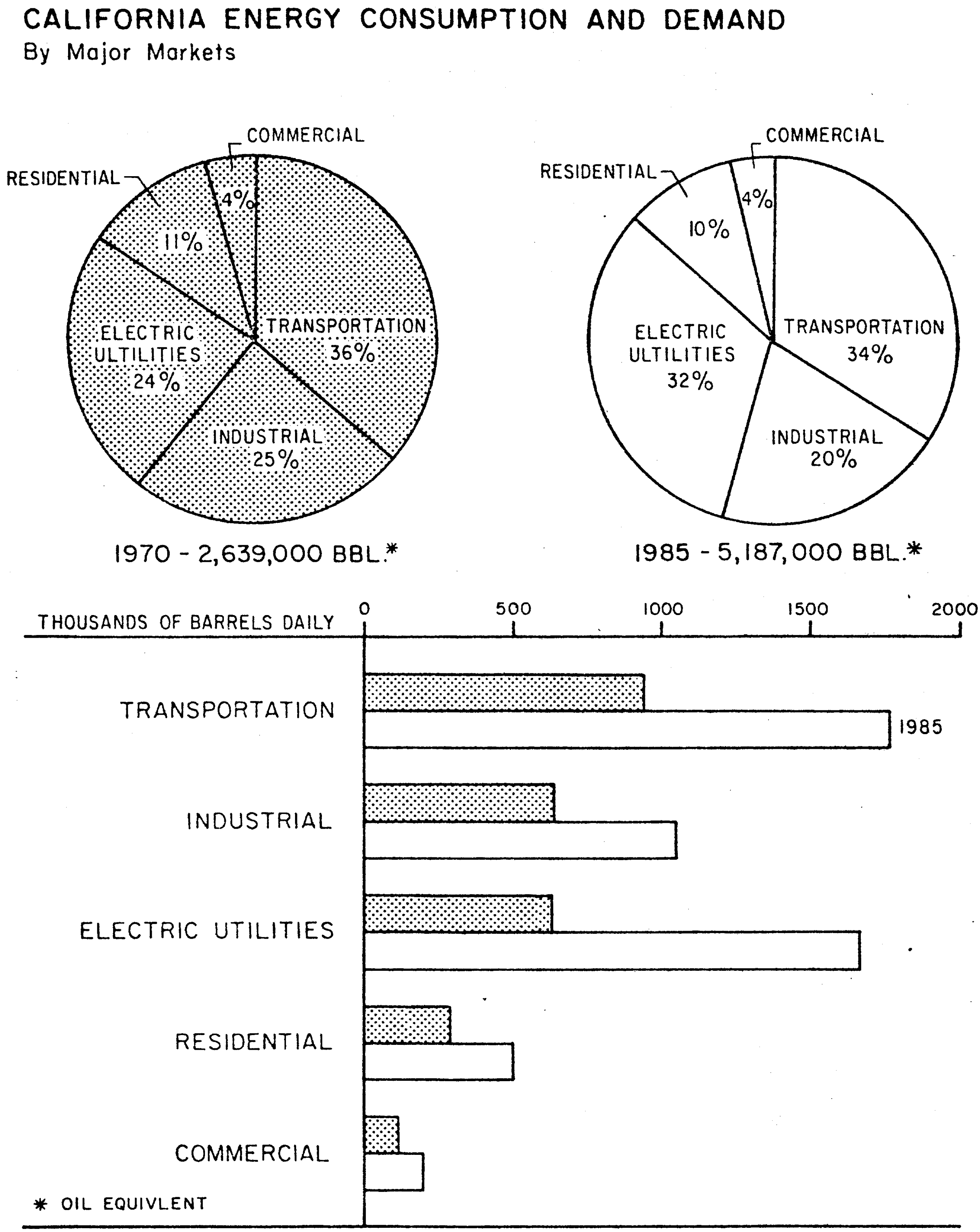


Figure 3: California Energy Consumption and Demand (Source: Reference 3, page 18)

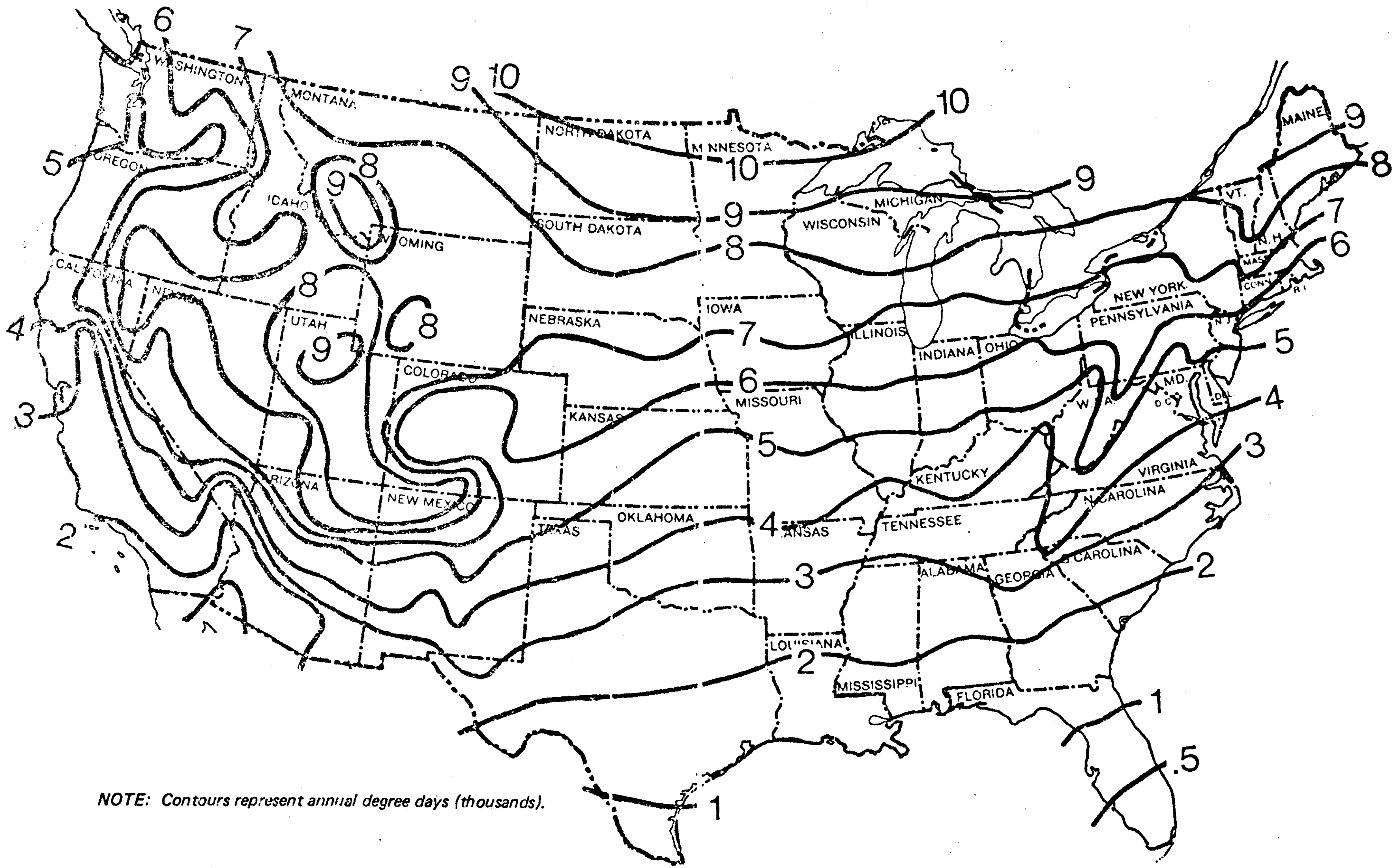


Figure 4: Relative Energy Requirements for Space Heating in the United States (Source: Reference 9, page 137)

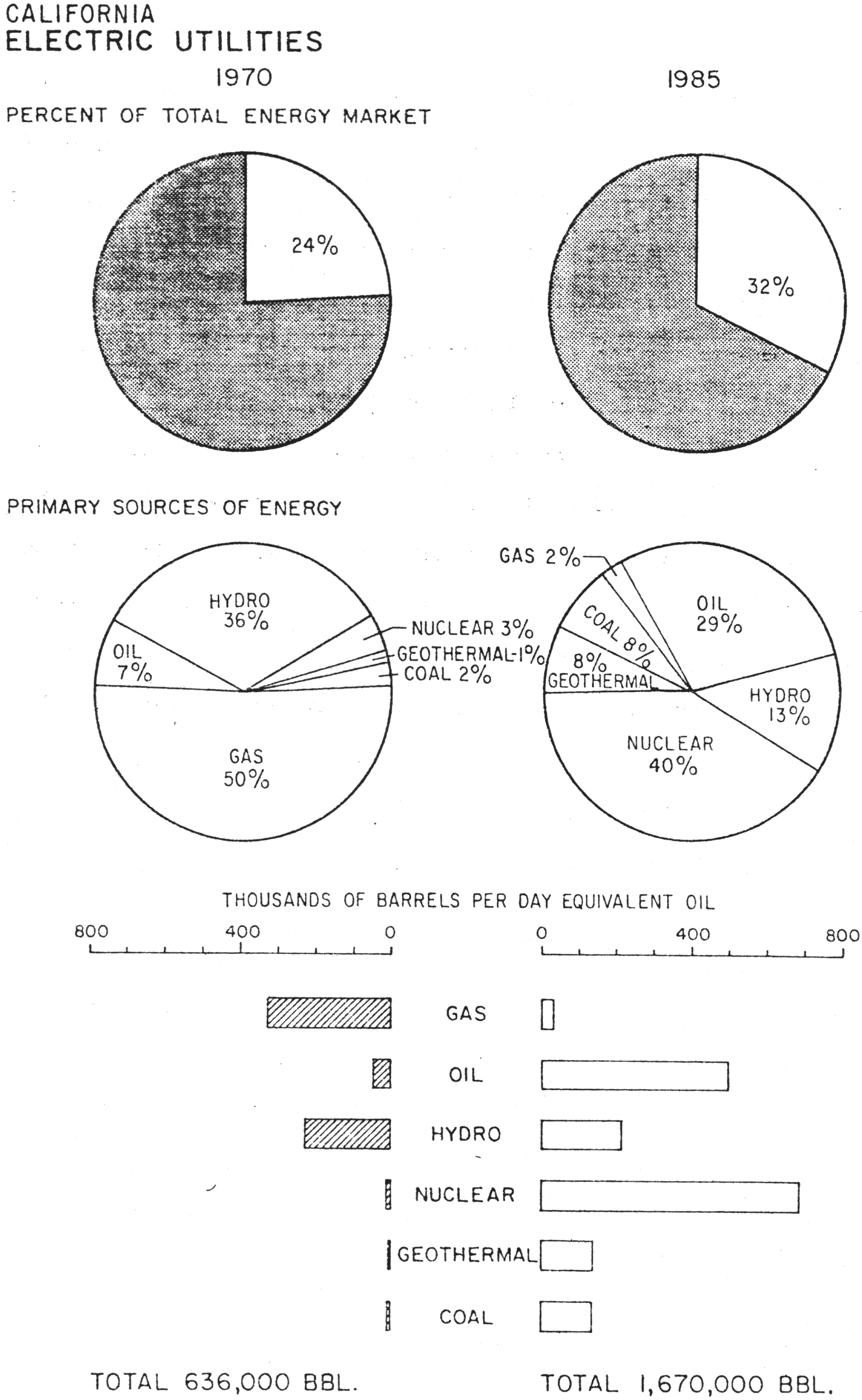


Figure 5: California Electric Utilities, 1970-1985 (Source: Reference 3, page 13)

and synthetic, 39 percent. Teller's low forecast for the oil supply for electrical utilities reflects the growing belief that oil supplies in the future will be conserved for the transportation sector of the market. By comparing the 1975 forecasts made by Teller for 1985 to the 1973 forecasts for utilities for 1985 made by the State Resources Agency[12] (see Figure 5), we can see the problem that is facing California utilities today: What energy supply sources can be substituted for the enormous quantities of imported oil once assumed to be easily available?

Part of this energy demand can be replaced by conservation. The energy demand forecast is variable, and downward trends are expected. Nevertheless, it seems unlikely that conservation can entirely reduce energy growth and its subsequent demand for new facilities.

One solution is to place greater reliance on coal. Southern California's utilities are planning rather ambitious projects for mine-mouth coal-fired plants outside the State in the Upper Colorado River Basin (see Figure 6). The unique problems associated with this endeavor are the special concern of this Bulletin.

COAL AS A FUEL SOURCE FOR SOUTHERN CALIFORNIA

Emphasis on Coal as a National Priority

President Ford has proposed a near-future target date for eliminating oil-fired powerplants from the nation's base-loaded electrical capacity.[13] Recommendations have also been made on the national level to require that "all new utility plants (those for which actual development has not yet begun) that are designed to use fossil fuels *per se* must burn coal either exclusively or as a second or third fuel as one of their basic energy sources, except for those plants that will use low-BTU coal-gas or other energy sources converted from fossil fuels."[14] These recommendations and others like them reflect national policy designed to reduce the dependence of the United States on foreign oil.

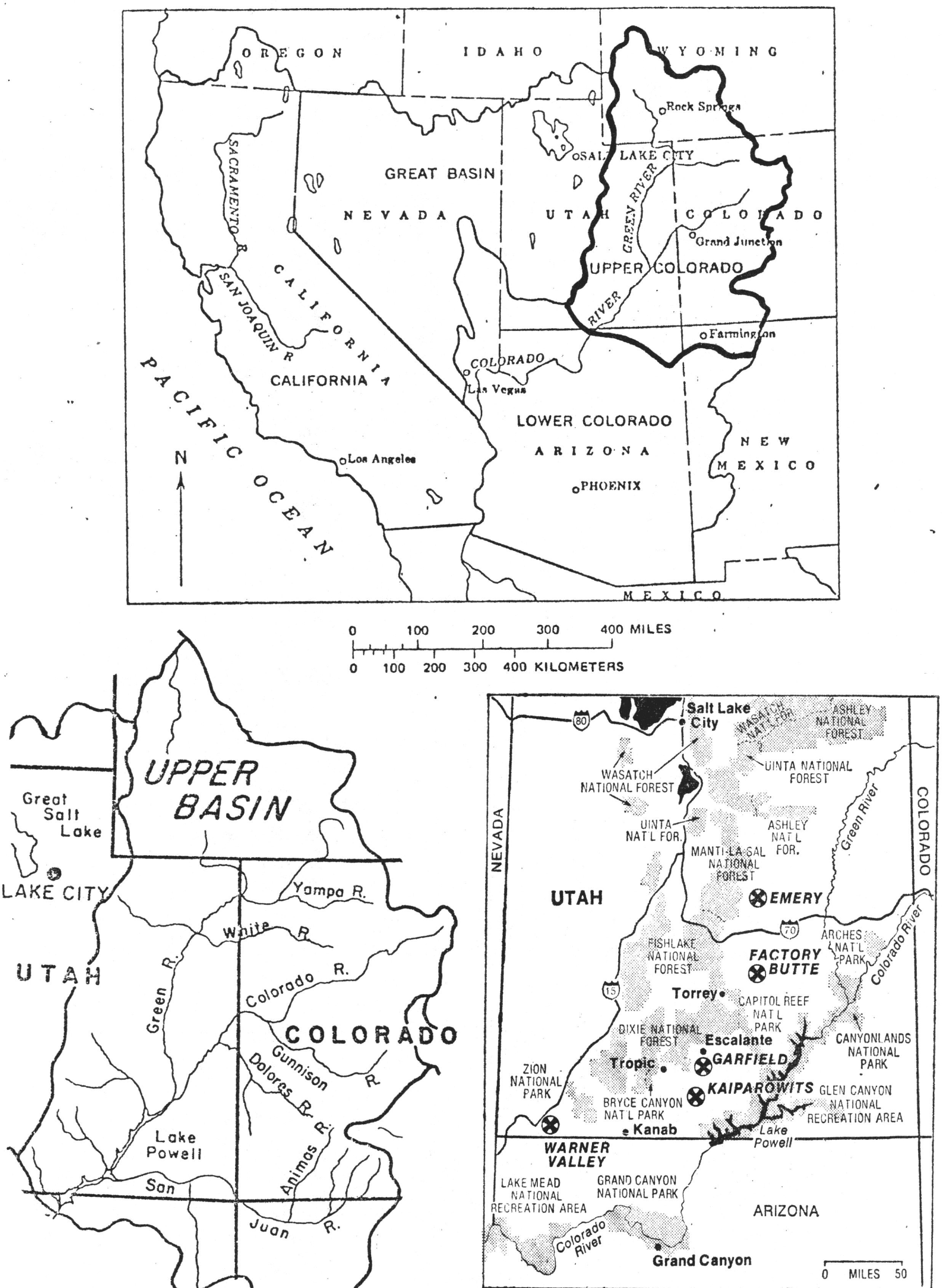
The projections of the utility industry indicate that the bulk of the nation's electrical power will be generated by nuclear energy in the year 2000, but that fossil fuels will still be the major energy source through 1985.

Industrial planners expect that the use of coal as a source of electric power in 1985 "will increase to between 180 percent and 275 percent over the 1975 level in the nation."[15]

The main checkpoints which constrain an increased role for coal in the nation's energy mix are current and proposed environmental standards. Some of these standards are now being viewed as "overly restrictive and counter-productive to other societal goals."[16]

California Coal as a Fuel Source for Southern California

As of January 1973, the coal reserve of California was reported to be 77.9 million short-tons, which was 0.00005 percent of the coal reserves of the United States.[17] "Coal found in California is generally of lignite or subbituminous rank, it has a low heating value, and generally makes poor fuel compared with coal mined in the Rocky Mountains and the eastern United States." As of 1973, "Coking coal for California's steel smelters is brought into the State, mostly from Utah, Colorado,



The New York Times/August 3, 1975

Crosses mark sites of proposed power plants in Utah

Figure 6: Upper Colorado River Basin and Coal Plant Sites in Utah (Sources: Reference 56, page 3; Reference 66, Plate 1; New York Times, August 3, 1975, page 34.)

New Mexico, and Oklahoma. This amounts to 17,000 barrels per day of equivalent oil. Additional coal, equivalent to 15,000 barrels of oil per day, is burned outside the State to generate electricity for California consumption."[17]

New Emphasis on Coal in Southern California Utilities

In response to the growing shortage of petroleum products, Southern California utilities are planning to obtain power from mine-mouth coal-fired powerplants in the Upper Colorado River Basin. The three major electric utilities (SCE, SDG&E, and LADWP) are presently pursuing plans for the construction of powerplants which are closest to Southern California load centers. These utilities have found that they can no longer depend upon natural gas suppliers to guarantee fuel for future powerplants. For example, LADWP recently constructed a gas-fired plant (Unit #3, Scattergood), but the gas supplier would not guarantee a future supply of gas. As a result, LADWP was forced to undertake a very expensive reconversion of the plant to use oil instead of gas. The prospect for increasing oil supplies to Southern California is not optimistic, in view of other regional demands for imported oil, particularly in the transportation sector. These utilities are therefore turning to a mix of coal- and nuclear-based plants to meet most of the future demand.

Southern California utilities already are using Colorado River Basin coal to generate electric power. SCE's share of the Four Corners Plant in the State of New Mexico is 690 megawatts (MW). The share of SCE and LADWP from the Mohave Plant near Las Vegas, Nevada, was 1,184 MW.[18] As of June 1, 1973, forecasts of new generating facilities for the period 1973-1991 showed that the new capacity and new units required in California in addition to plants operating in 1972 would be distributed as follows:[19] 54.9 percent nuclear; 9.6 percent coal; and 14 percent oil and gas.

In the same projection, all the coal-fired plants were located outside the State of California--the new capacities being 281 MW at the Mojave Plant in Nevada; 550 MW at the Navajo Plant in Page, Arizona; 4,999 MW at the Kaiparowits Plant in Utah;[20] and 1,300 MW at the Arrow Canyon Plant in Nevada. This projection was made before the oil embargo in the fall of 1973.[21A]

NEW PROPOSALS TO DEVELOP UTAH COAL FOR SOUTHERN CALIFORNIA POWER

The Intermountain Power Project Plant

Since publication of the Energy Dilemma, the Intermountain Power Project (IPP) has been formed, in which public power companies of Southern California are the main stockholders. This group plans the construction of a coal-fired powerplant near Caineville, Utah, which will burn 9 million tons of coal yearly. The IPP is a non-profit corporation under Utah general law. Its aim is to produce 3,000 MW by the year 1982 at the Caineville site. This power would be distributed among six municipally controlled utilities in Southern California and the Intermountain Consumers Power Association (ICPA). The ICPA is a public power consortium of Utah and currently supplies power to 26 Utah municipal and cooperative power suppliers. The City of Los Angeles has been assigned the task of conducting the IPP feasibility study and could possibly undertake the final project engineering.

The seven public utilities comprising IPP, and their percentages of participation in the Project, are as follows:[21B]

IPCA (public power companies of Utah)	15 percent
City of Anaheim (California).	15 percent
City of Glendale (California).	2-1/2 percent
City of Burbank (California).	2-1/2 percent
City of Los Angeles (California)(LADWP)	50 percent
City of Pasadena (California).	5 percent
City of Riverside (California).	10 percent

IPP holds no coal leases in Utah, but expects to have no trouble buying coal from the Kaiparowits, Emery, or Wasatch Plateau coalfields:

> "Coal for the project will be obtained from nearby Utah coalfields and transported to the site possibly by railroad, conveyor, or slurry. Potential coal resources are located in Sevier, Emery, Wayne, and Garfield Counties. A detailed study of coal resources, fuel economics, delivery and related matters will be completed during the feasibility study."[21B]

A map showing the location of the IPP in Utah is shown in Figure 7. The location of coalfields in southern Utah is shown in Figure 8.[22]

The Kaiparowits Plant

The Kaiparowits Project is a consortium of private power companies (as distinguished from the public power consortium, IPP) which has proposed to develop some of the coal reserves of the Kaiparowits Plateau. This consortium was formed by SCE (through its wholly owned subsidiary Mono Power Company), Arizona Public Service Company (through its wholly owned subsidiary Resources Company), and SDG&E. The Salt River Project, a founding member of the Kaiparowits Project but not presently in the consortium, is a public company. The consortium plans to construct a 3,000-MW coal-fired powerplant in the southern half of the Kaiparowits Plateau.

The Kaiparowits Project is further along than is IPP, in that it has definite access to sufficient water and coal resources, and the Draft Environmental Impact Statement (EIS) has been completed by the Bureau of Land Management. The three utilities which are participants in the Kaiparowits Project together have a total of nearly 48,000 acres of coal lands under lease on the Plateau. (In some documents this is listed as leased to the Resources Company.)

The participants that make up the Kaiparowits Project, and their percentages of participation in the Project, are given below:[23]

Arizona Public Service Company	18 percent
Salt River Project . . . . . (now withdrawn)	(10 percent)[24]
SDG&E	23.4 percent
SCE	40 percent
Unsubscribed	18.6 percent

A number of other projects in the Kaiparowits coalfield include companies not based in California. Utah Power & Light Co. has an exploration program for the development of a 2,000-MW plant near Escalante, Utah. This is shown as the Garfield Plant in Figure 6. El Paso Natural Gas has purchased lease rights to about 35,000 acres of coal lands.

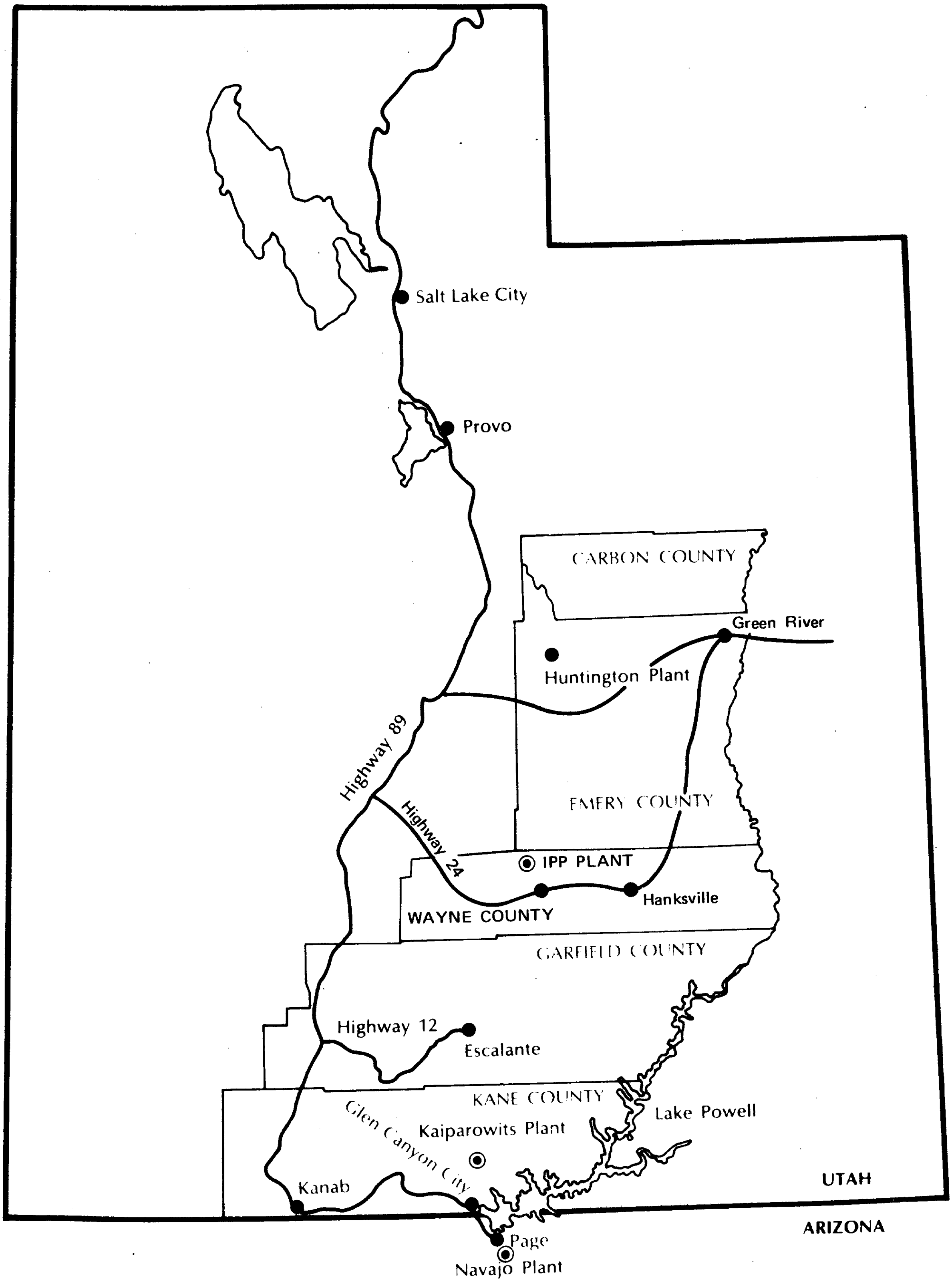


Figure 7: Utah Counties with New Coal Developments (Source: Reference 1, page 32)

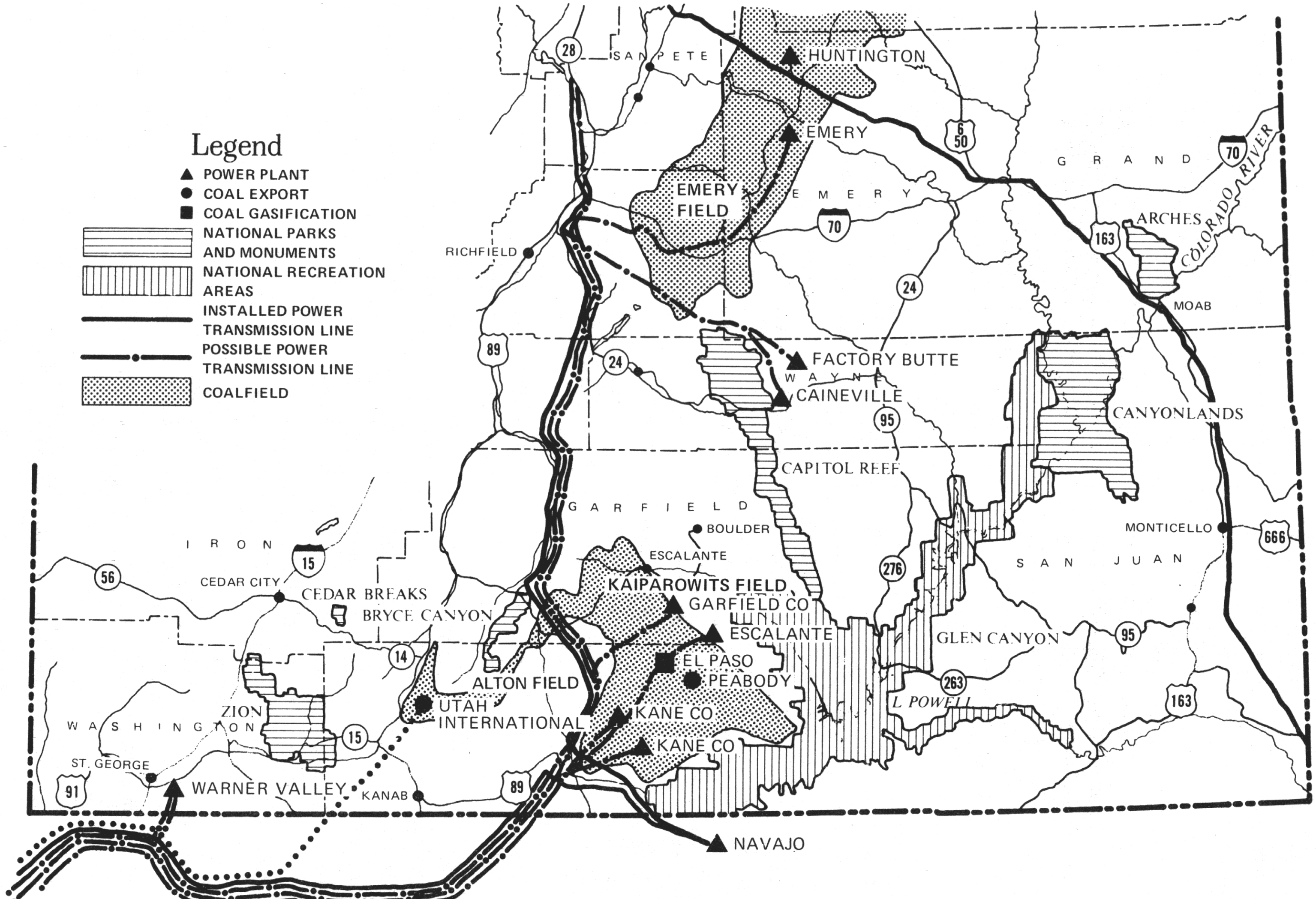


Figure 8: Proposed Coal Developments and Electrical Transmission Lines in Southern Utah

Peabody Coal Co. has leased nearly 30,000 acres of Federal and state coal lands near the center of the Kaiparowits coalfield.[25] A number of these activities, including the Kane County locations of the two proposed sites for the Kaiparowits Project, are shown in Figure 8. Of all the activities, the two projects of most interest in this study are the Kaiparowits Project and IPP. There are major differences between these two projects.

The Kaiparowits Project has its own coal resources and has a contract to obtain surface water from Utah's allotment of the Colorado River system. The water supply for the Kaiparowits Project is based on the project's water rights application for appropriation of surface water, and the contract is the mechanism for exercising that appropriation. The significance of the two--the appropriation and the contract--is set forth in the Draft EIS for the Kaiparowits Project (pp. I-316 through I-320). IPP has a lease application for ground water and thus is not entirely dependent upon surface water rights for the success of the project (although it has an application for rights to the surface water in the Fremont River). IPP does not own any coal leases, but expects to purchase Utah coal from surrounding coalfields. The preliminary work for the Kaiparowits Project is completed. Construction now is delayed pending the approval of access permits. The planning for IPP is only partially completed.

The approximate annual peak demands in 1974 for the three utilities of Southern California are 10,000 MW for SCE; 4,000 MW for LADWP; and 2,000 MW for SDG&E. This is shown in Figure 9.[26] The amount of power going to SCE from the Kaiparowits Project would be 1,200 MW; the amount going to SDG&E from the Kaiparowits Project would be 690 MW; and the amount going to LADWP from IPP would be 1,500 MW. A summary of the forecasts for the coal percentages used in Southern California utilities for 1984 has been presented in Table 1. These estimates do not include the possibility of the Southern California utilities purchasing power from Nevada Power Company. The total percentages of coal-based power in Southern California will increase if Nevada Power Company sells power to Southern California utilities from the proposed Warner Allen Plant under consideration for construction in southeast Nevada.[27]

Although virtually all the coal-based electric power will come from outside California, it does appear that Southern California utilities will approach about half of the 1985 target listed in Teller's report: 34 percent of electrical energy produced by coal[28] (Table 2). The projected use for coal-fired electrical power in Northern California is small. There, electric power will be derived mainly from nuclear, oil, gas, hydroelectric, and geothermal sources. This energy-mix may change.

The importance of coal to Southern California utilities in the future justifies a detailed study concerning the problems arising from the use of Utah coal and Utah powerplants to produce power for Southern California use. The present study is restricted to only one aspect of the general problem. It focuses on the energy production in the Kaiparowits Plateau area, and only briefly considers the implications of the IPP proposal.

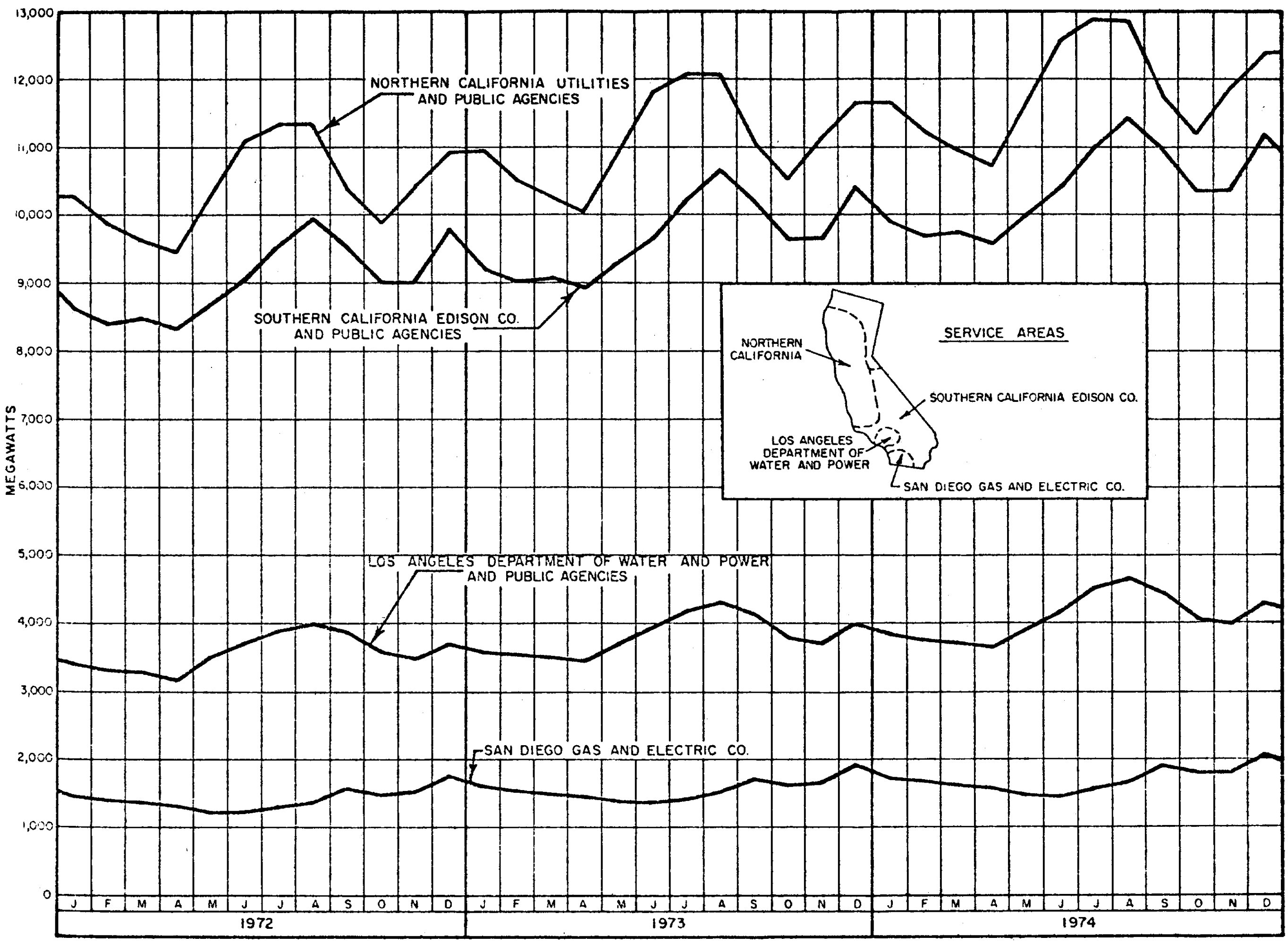


Figure 9: Forecasts of Monthly Peak Loads in California, 1972-1974 (Source: Reference 1, page 25)

Coal Reserves in Western States Available to Southern California

If Southern California is to substitute coal for gas and oil in its power mix, it must look towards the coalfields which lie nearest to the west coast (see Figure 10). The Kaiparowits region of southern Utah contains the closest major coalfields to Southern California, and it has the attraction of abundant coal with relatively low sulfur content per BTU. Southern California could (and does) obtain some of its coal-fired power from several large coalfields in the Southwest, such as those in the Four Corners region (northwestern New Mexico), on Black Mesa in Arizona, in central Utah, or in Wyoming. However, the quantity of coal in Black Mesa is minor compared to that in southern Utah and northwestern New Mexico. The New Mexico coalfields are large, but they are farther from California than are those in southern Utah, and, furthermore, they are located on the Navajo Indian Reservation. The Navajo Tribe currently is negotiating coal gasification contracts with El Paso Natural Gas and with Western Gasification Company (WESCO) to use the coalfields in northwestern New Mexico.

The closest and earliest source of coal-based energy for Southern California is the Kaiparowits Plateau.

The various Utah coalfields are shown in Figure 11, modified slightly from Doelling and Graham,[29] which shows that the Kaiparowits coalfield is characterized by being fairly low in sulfur content. Kaiparowits coal has no coking properties, and in some areas it would require cleaning to assure adequate quality for powerplant use. Some of the Kaiparowits coal has a high BTU content, although it shows considerable variation. The coal generally can be described as medium-sulfur coal[30] (Figures 11 and 12). It can also be described as a medium-ash coal[31] (Figure 13).

Some national surveys imply that the majority of western coalfields are strip-mined. While that is true for the coalfields of Wyoming, New Mexico, and Arizona, the great majority of Utah coalfields are deep-mined. A number of technical factors (in addition to depth of overburden) determine whether it is more economical to deep-mine or to strip-mine the coal. While the Alton coalfield and the northern part of the Henry Mountains coalfield are strippable,[31] the coal for the Kaiparowits Project will be deep-mined.

The environmental problems associated with reclaiming land from strip-mining operations will be of no concern in the Kaiparowits Project. However, deep-mining, as is necessary at Kaiparowits, brings a special class of safety and social problems.

There is a vast amount of coal available in the Kaiparowits Plateau. Some recent statistics are given in Table 4. A reserve is designated as that portion of the identified resource from which a usable mineral can be commercially extracted by present mining methods. The U.S. Bureau of Mines, in a recent bulletin,[32] listed 4 billion tons as the quantity of coal <u>reserves</u> of Utah. However, the coal <u>resources</u> of Utah are listed as 32 billion tons[33] by industry.

The coal <u>reserves</u> of the Kaiparowits Plateau are listed as 2.9 billion tons.[34] The coal <u>resources</u> of the Kaiparowits Plateau are listed as between 15 and 40 billion tons, as shown in Table 4. Resources Company has estimated that the difference

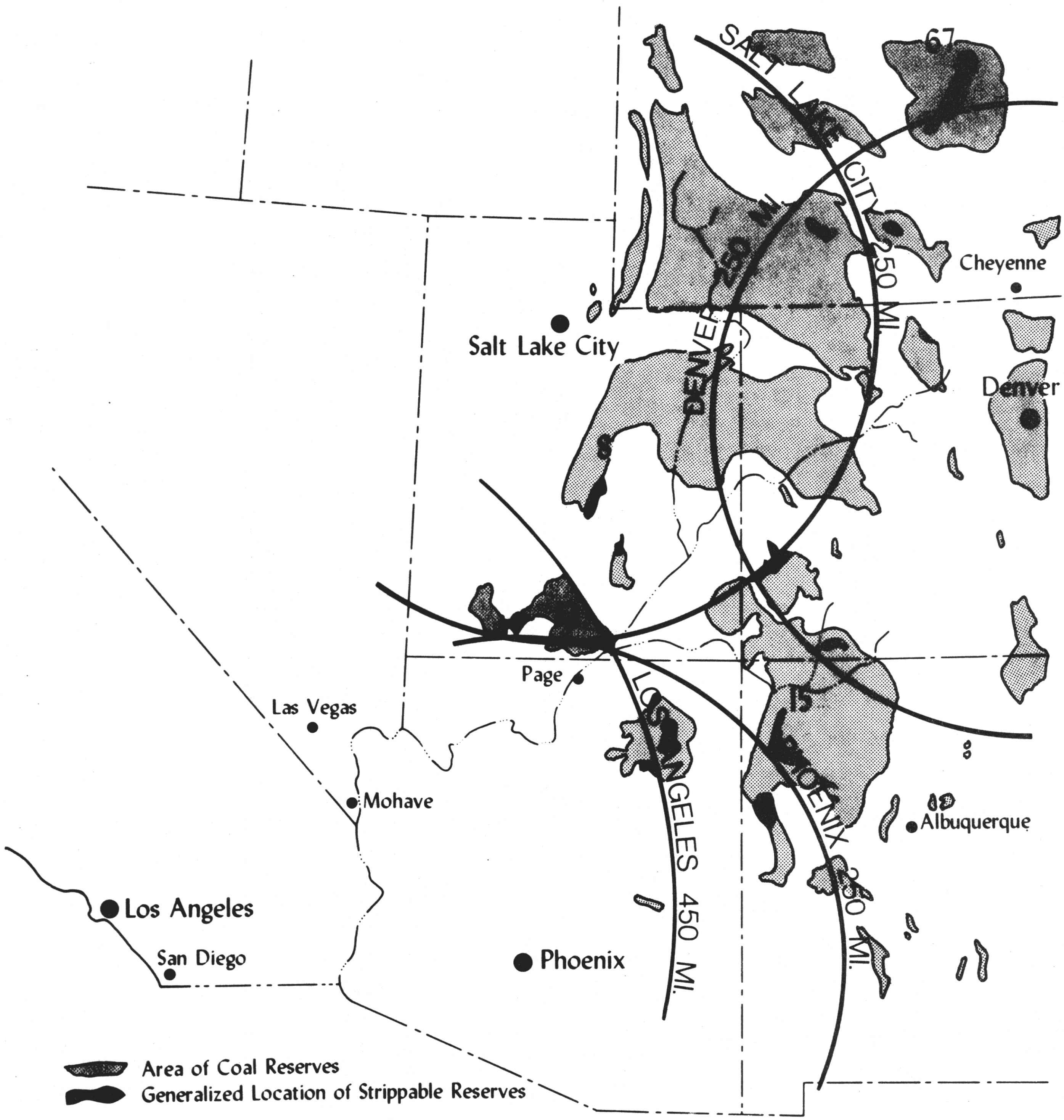
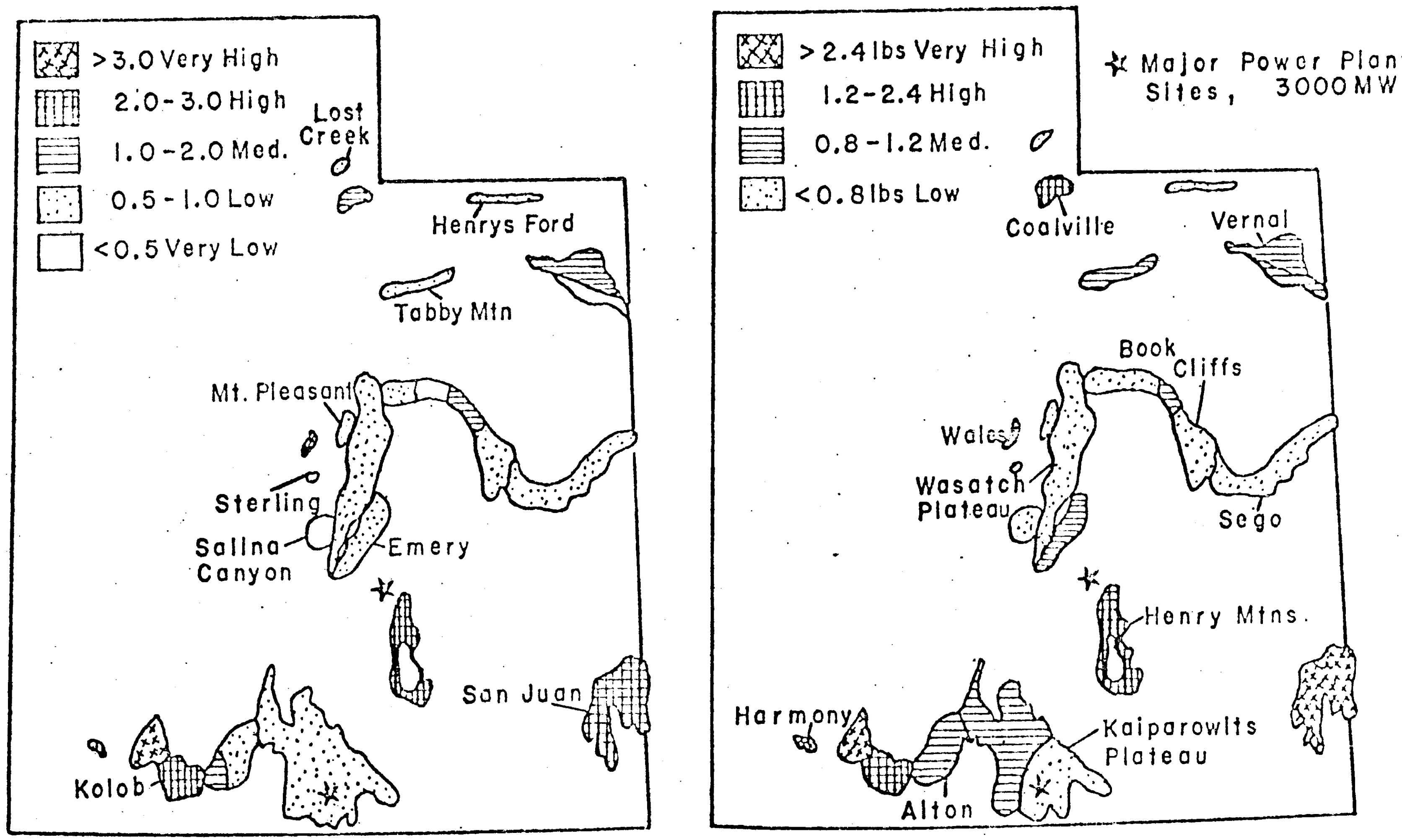


Figure 10: Coalfields of the Southwest



Percent Sulfur by Weight

Lbs Sulfur per One Million Btu

Figure 11: Sulfur in Utah Coal (Source: Reference 22, page 31)

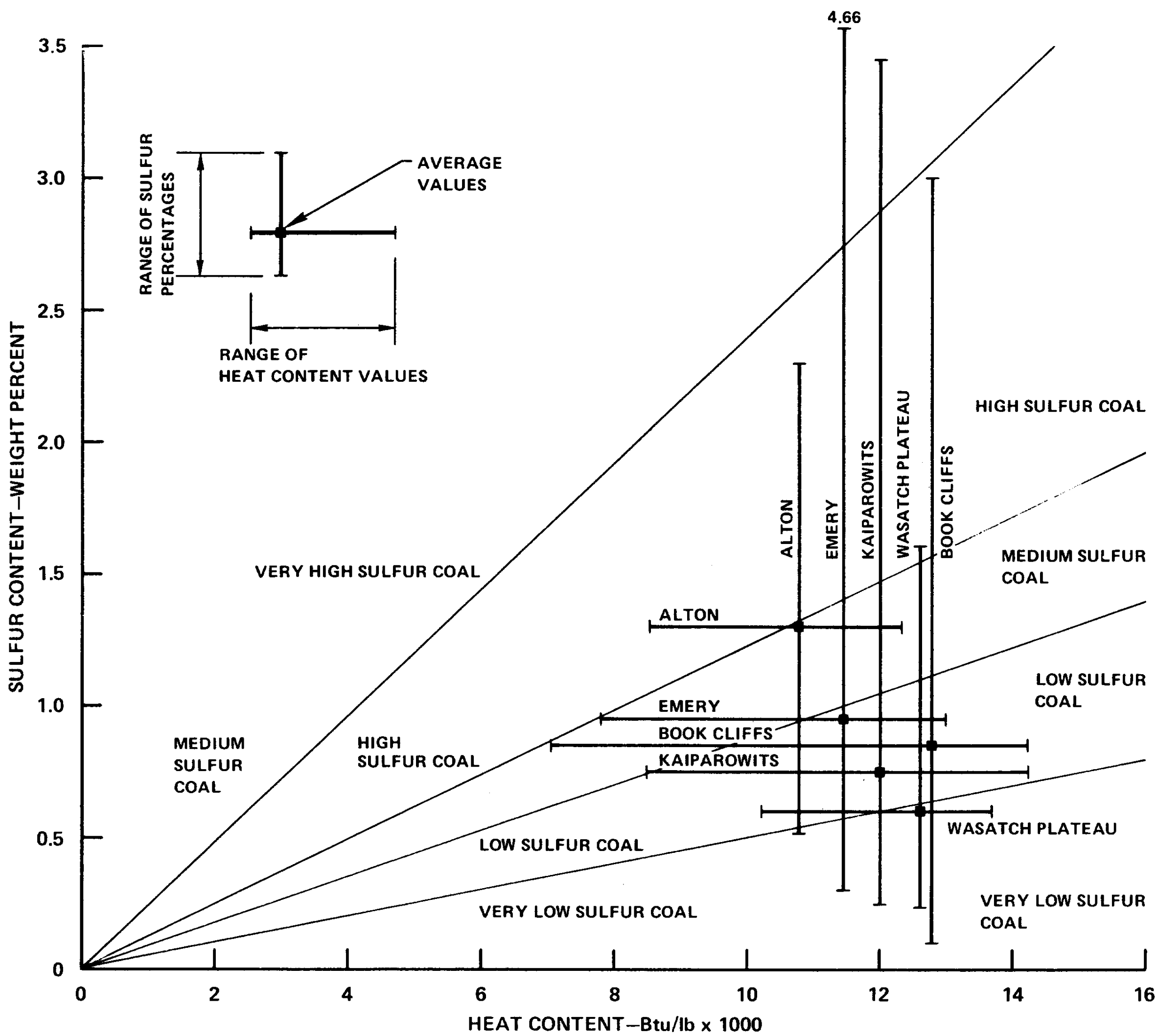


Figure 12: Sulfur and Heat Content of Utah Coals (Source: Reference 22)

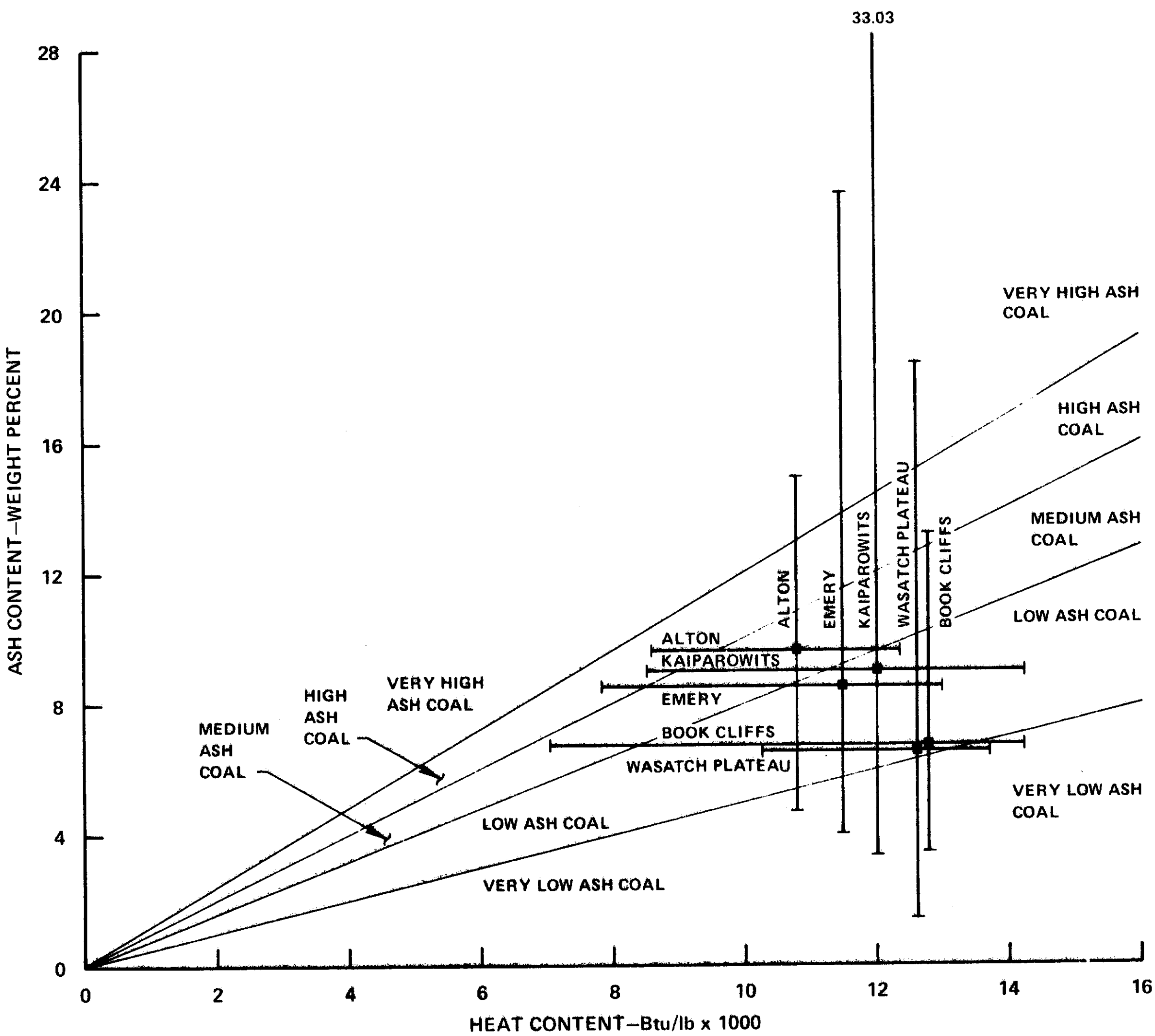


Figure 13: Ash and Sulfur Content of Utah Coals (Source: Reference 22, page 34)

Table 4: Changing Estimates of Quantity of Coal in the Kaiparowits Plateau

Year	Source	Amount
1961	U.S. Geological Survey Initial gross estimate of reserves in beds over 14 inches thick and under less than 3000 feet of overburden. Based on a few measurements of coal thicknesses made by Gregory and Moore (1931) and on general considerations of the thickness and nature of the coal-bearing rocks.	3 billion tons
1969	U.S. Geological Survey Resources determined from mapping and exploration for coal with up to 3000 feet of overburden. Estimate by F. C. Peterson based on detailed mapping then in progress, with estimate that potential total would be much larger.	7.3 billion tons
1972	Utah Geological and Mineralogical Survey Coal reserves based upon geologic and geographic position and coal outcrop and drill-hole information where available. Includes coal in beds more than 4 feet thick and under less than 3000 feet of overburden.	15.2 billion tons
1974	U.S. Geological Survey Unpublished information based on mapping and coal drill-hole information. This is a gross estimate of total resources made for in-house use and includes coal in seams as thin as 14 inches and coal under as much as 6000 feet of overburden. This figure is being revised upward as of November 1974.	40 billion tons

Source: Table 1, Reference 22.

between coal resources and coal reserves is approximately a factor of two. For their lease, they estimate 611 million tons in coal resources and 308 million tons in coal reserves.[35]

Thus, coal from the Kaiparowits region not only is the closest geographically to Southern California, as is shown in Figure 7, but it has relatively high heat content, relatively low sulfur content, and occurs in vast quantities.

Coal from Alaska

Other coalfields conceivably accessible to California through sea transportation are in Alaska. The Division of Geological and Geophysical Surveys of the State of Alaska has estimated Alaskan coal resources as follows: 132.9 billion tons in total recoverable coal resources and 2.029 trillion tons in total demonstrated inferred and hypothetical coal resources.[36] On the other hand, the Bureau of Mines has listed the coal reserves of Alaska as 11.6 billion tons.[32] The coal most available for exploitation lies in the Susitna coalfield (in the Beluga-Yentna area), in which the "demonstrated coal resources are 2.4 billion tons."[36]

The cost of Alaskan coal may be prohibitive to Southern California utilities because of high interstate sea shipping rates and the problems of burning coal within California. The possibility of using Alaskan coal is not considered by Southern California utilities at this time, and in fact they have concentrated their search for coal resources on the Colorado Plateau. However, technical innovations for burning coal may make Alaskan coal far more attractive for Southern California power than it is today.

WATER RESOURCES IN THE COLORADO RIVER BASIN

The Connection Between Water and Coal Resources

If the energy resources of the Upper Colorado River Basin are to be exploited in sufficient amounts to relieve the energy bind of the nation, in particular that of the Southwest, then correspondingly large amounts of water in the Upper Colorado River system are required for the energy development, unless the technology of power development is changed.

The amount of water available for energy resource development in the Colorado River Basin is limited by the physical supply and the Law of the River[37] which is a body of statutes, compacts, executive directives, and court decisions. A major component of the Law of the River is the 1922 Colorado River Compact. Under this Compact, the Colorado River Basin is divided into an Upper Basin and a Lower Basin which are each apportioned waters from the Colorado River system. It is contended by interests in the Lower Basin states that the states of the Upper Division (Colorado, New Mexico, Utah, and Wyoming) are obligated to deliver at least 75 maf during any period of 10 consecutive years to Lee Ferry (on the boundary of the Upper and Lower Basins), plus one-half of the deficiency in surplus water to satisfy the Mexican Treaty obligations. The 1948 Upper Colorado River Compact apportioned the waters allocated to the Upper Basin by the Colorado River Compact by granting to the states of the Upper Division a percentage of the apportioned water and to Arizona an annual amount of 50,000 acre-feet (a small part of Arizona is located in the Upper Basin). Under these Compacts, each of the Colorado River states is apportioned a particular share of water either as a percentage of river flow or as a fixed quantity (e.g., a number of acre-feet) of the Colorado River water. The states do not regard the amount of Colorado River water apportioned to them as sufficient for their needs, so existing allotments are jealously guarded.

In the Upper Colorado River Basin, the area containing energy resources (coal, oil shale, oil, natural gas, and uranium) is very sparsely populated (the larger towns are Rock Springs, Wyoming; Grand Junction, Colorado; Price, Utah; and Farmington, New Mexico). Energy is exported from the Upper Basin into the populated load centers. In the sparsely populated areas, energy projects are planned to be coincident with the location of the resources, but these are the very areas in which surface water is scarce. If mine-mouth powerplants are constructed, the water allocated to the state containing the energy resource must be used for the production of the energy, in spite of the fact that the energy often is being produced for consumption in another state. The Law of the River is such that it is extremely unlikely in the short term that institutional arrangements can be made to transfer a water right from a state using the energy to the state in which power is actually produced.

For these and other reasons, it is very important to quantify the amount of water that is in the Colorado River, so that the quantity apportioned to each state can be estimated as accurately as possible. Any proposed power project must have relatively secure water rights in order for financing to be obtained, yet the state engineer who awards this water right to the project has to be sure that the amount of water awarded actually is available under conditions of variable water flow and in the context of other demands and rights.

The Importance to the Upper Basin of Quantifying River Flow

The surface water supply of the Colorado River system is the estimate of the average annual supply (that is, available for consumptive use) calculated for a reasonably long time (such as several decades). Estimates vary greatly as to the amount available. There exist optimistic estimates of the river flow which imply that no overall shortages will occur until the turn of the century. Pessimistic estimates indicate that the annual demand could outrun the renewable annual supply in slightly over a decade. Since the lead time for the construction of a large energy project presently exceeds 7 years, the question of whether the pessimistic or optimistic estimate of the river's water supply should be used as the working hypothesis can be crucial to the assignment of the necessary water rights to large power projects. Unless the water right can be shown to be reasonably secure for the lifetime of the project, the necessary financing for an energy project cannot be obtained.

The surface water supply of the Colorado River is measured or computed at Lee Ferry, Arizona (the boundary point between the Upper and Lower Basins). The annual flow fluctuates greatly, so the predicted quantity of the average undepleted flow of the river depends greatly upon the historical period chosen for computation.

Various Techniques for Estimating River Flow

The data available for estimating the flow of the Colorado River fall into three categories: historical flow, virgin flow, and reconstructed flow. Historical flow is the most accurate, being the actual measured flow at the U.S. Geological Survey (USGS) river gaging stations. The records for the station at Lee Ferry are actually the sum of the flows of the Paria and Colorado Rivers as measured by gages on these two rivers. Virgin flow is an estimate of what the flow would be if it were not modified by withdrawal for irrigation, export, municipal, industrial, and other consumptive uses. It is determined by adding estimates of consumptive use to historical flow. The figures for consumptive use are a combination of measured diversions and estimates of consumptive use. Because of various problems in estimating consumptive use, virgin flow figures are less accurate than are those for the historical flow. One disadvantage of all methods based only on historical flow, however, is that the flow has not been gaged long enough for determinations to be made of long-term climatic change.

Reconstructed flow is determined by calibrating some longer term data with historical or virgin flow, and then using the longer term data to calculate flow for years before gaging was done. One type of long-term data is tree-ring information. Tree-ring data calibrated by comparison with virgin flow can be used to reconstruct virgin flow. Although the reconstructed flow data will be somewhat less accurate than those for historical flow, this technique has the advantage of allowing estimates to be made of the climatic fluctuations over much longer periods (such as several centuries).

Briefly, in the last decade the historic stream gage flow data have been used to give the most optimistic estimate of streamflow (near 15 million acre-feet per year), while the tree-ring studies have been used to arrive at the most pessimistic estimate (near 13.5 maf per year). Nominally, at least, 8.25 maf per year of water is delivered at Lee Ferry to the Lower Basin. Using the figure of 8.25 maf per year for that flow not available to the Upper Basin,[38] the most optimistic estimates of average river flow result in a remainder of 6.5 maf per year to be shared by states of the Upper Basin, while the most pessimistic view of the river flow results in 5.25 maf per year to be shared.[39]

For periods before the last decade, historic stream gage records were used to project annual flows which were on occasion similar to those reconstructed from tree-ring studies. This will be discussed below.

A recent study by the Department of the Interior[40] stated: "Estimates of supply [for the Upper Colorado River Basin] range upward from a conservative figure of 5.8 maf per year to about 6.5 maf annually." This latter figure illustrates the optimistic view. Weatherford and Jacoby[39] reported "The hydrology studies of the Lake Powell Research Project [using tree-ring methods] estimate that the reconstructed virgin runoff from the Upper Colorado River Basin has a mean of 13.5 ± 0.5 maf per year" [or about 5.25 maf per year from the Upper Basin, assuming 8.25 maf is required for delivery downstream]. This estimate represents the pessimistic view. Using projections made by the Department of the Interior[40] for planned growth in food and fiber production as well as in energy development, a collision between supply and demand obviously will occur much earlier, at the 5.25-maf-per-year level of supply than at the 5.8-maf-per-year level of supply[41] (Figure 14). Other projections are currently being made in which secondary economic effects, such as increased efficiency, are factored into the calculation of the collision between water supplies and water demands. It is possible that consideration of these effects will prolong the collision beyond that indicated by Figure 14, but additional research is urgently needed to refine further the estimates of average river flow, as well as to refine the forecasts of the growth of energy demand.

There has been at least one recent estimate of river flow which is between the values of 13.5 and 15 maf per year. Holburt[42] reported an estimate by the Colorado River Board of California that 13.8 maf per year would be the maximum dependable flow. This estimate, made prior to 1965, allowed for historic annual flows, upstream storage capacity for long-term regulation, and maximum control of upstream annual release.

Holburt[43] also reported that by using probability analysis one could estimate that there is a 50-percent chance that the long-range undepleted flow of the river at Lee Ferry would equal or exceed 14.9 maf per year. This estimate was used by Lower Basin representatives in testimony before the House of Representatives in 1965. Conversely, it may be added, there is a 50-percent chance that the flow will be less than 14.9 maf per year, using the same data in Holburt's calculations.

Early Estimates of the Colorado River Flow

The 15-maf-per-year figure now used by the Department of the Interior for the long-term average flow is its recent estimate taken from the record of gaged flow. As years pass and additional years of record become available, the long-term average flow as calculated by the Bureau of Reclamation becomes revised. Many different figures for the long-term average flow have been used by the Department of the Interior in the past.

In 1925, 3 years after the signing of the Colorado River Compact, E. C. LaRue published graphs in a U.S. Geological Survey Water Supply Paper showing "estimated annual discharge of Colorado River at Lee's Ferry, 1851-1922."[44] The graphs depicted (a) annual flow "without correction for depletion" with a mean of 16 maf per year; (b) annual flow "corrected for past irrigation depletion" with a mean of 14.3 maf per year; and (c) flow with "complete irrigation development in the Upper Basin" with a mean of 8.81 maf per year.

In the summer of 1921, the U.S. Geological Survey, in cooperation with SCE, had established the first gaging station at Lee Ferry.[45] In 1922, the Colorado River Compact was signed, allocating water to the Upper and Lower Basins with a division point at Lee Ferry. By the summer of 1923, the Lee Ferry gage had recorded 2 full years of data, giving a measured discharge of 16.372 and 16.135 maf per year for 1922 and 1923 respectively.[46]

In 1925, hearings concerning the Colorado River Basin were held before the Committee on Irrigation and Reclamation of the U.S. Senate. During these hearings, George H. Maxwell, Executive Director of the National Reclamation Association, stated that "the Colorado River is a very erratic stream, its annual flow varying from about 8 maf per year to 25 maf per year. A standardization of that flow of

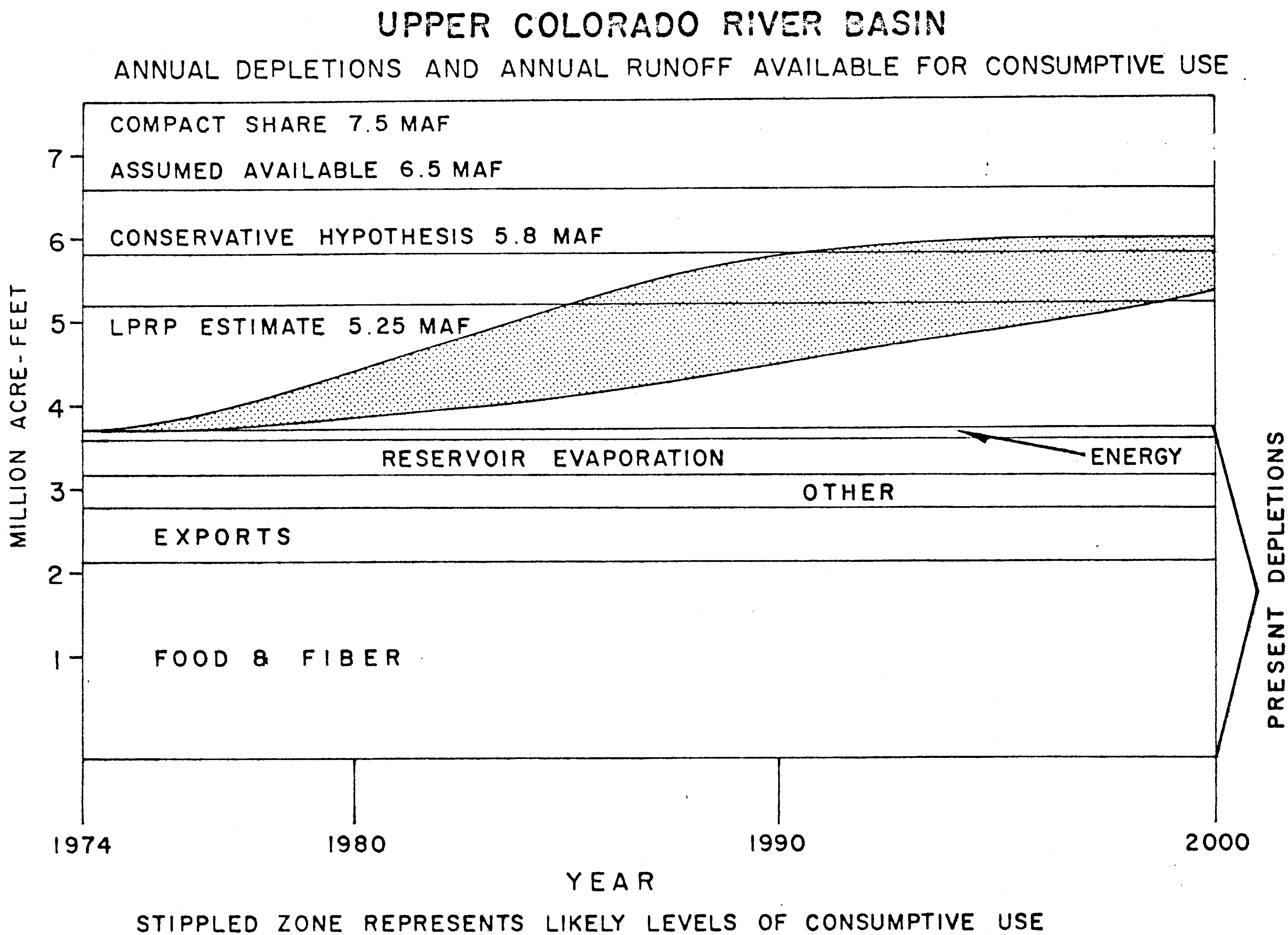


Figure 14: Surface Water Available for Consumptive Use in the Upper Colorado River Basin (Source: Reference 41, Fig. 4, p. 17).

the river averaged over 20 years would produce a regulated flow of 16 maf per year."[47] Such estimates of river flow were used to support proposals in the 1920s for a large dam to be built on the Colorado River.

Late in the 1920s and in the 1930s, the Department of the Interior held, in general, that the unreconstructed flow was less than 16 maf per year.[48] In fact, in 1928 the so-called "Sibert Board" calculated that the average river flow at Black Canyon was 15 maf per year, "an amount more than 1 maf per year less than the Reclamation Service had estimated in 1922... The error was attributed (in part) to... failure to take adequately into account the years of unusually low flow prior to 1905."[49]

In advance of the 1956 Colorado River Storage Act, representatives of the Bureau of Reclamation reported that the average virgin flow of the Colorado River was 15.4 maf for the 40-year period 1914-1953.[50,51] It is quite likely that at one time or another there was issued an internal Department of the Interior report in which it was estimated that the annual mean virgin streamflow using historical flow data is 13.5 maf per year. Thus, historical streamflow data have been used to predict a virgin flow of about 13.5 maf per year many years before the same figure was reconstructed from tree-ring analyses.[41]

Holburt[52] reported that a 35-year sample of river flow is a poor sample due to the lengths of wet and dry periods, and that this shows up in a probability analysis. Obviously, long periods of gathering streamflow data are required in order to arrive at good mean virgin flow estimates. The question is: How long a period of measurement is required in order to obtain a mean flow reliable enough for forecasting in the next three decades? An indication of the answer can be obtained from the tree-ring analyses.

Long Hydrologic Cycles Evidenced from Tree-Ring Analysis (Hydrodendrochronology)

The analysis of the hydrologic record clearly shows that there was a bountiful supply of Colorado River water from about the turn of the century until 1930. The average flow in the river has been lower since then. The concern is: Can the long-time average water supply of the river be expected to return to the level it had been in the early 1900s?

Analysis of tree-rings by the Laboratory of Tree-Ring Research at the University of Arizona indicates that the wet period of 1905-1930 evidenced by the hydrologic record was a rare event in the history of the river.[53] The only comparable wet period indicated by the tree-ring chronologies was in the early 1600s. The tree-ring record indicates extended periods of drought in the late 1500s and the late 1800s. Although, of course, corresponding hydrologic measurements are not available to confirm this, there is some historical and archaeological evidence which can be used to support these conclusions.[54] Statistical averaging of the hydrologic record from 1900 to the 1970s would yield an overestimate of the average supply for the next several decades, because the average would include substantial data from an abnormally wet period. If the amount of water flow must be known for planning power production enterprises, a more conservative approach would be to average the supply reconstructed by the 400-year tree-ring chronology. It has been statistically demonstrated that there is a close relationship between tree-ring width and streamflow. The long-term mean annual virgin flow based upon tree-ring analysis is 13.5 ± 0.5 maf.[54] The figure of 13.5 maf per year may change slightly with further research and analysis, but the warning to energy- and water-policy planners is clear. They should expect that wet periods of flow in the river basin can be separated by long dry periods, and a good estimate of mean annual flow is about 13.5 maf per year. In spite of the wet 1974-1975 winter, there is evidence from the tree-ring record coupled with the hydrologic record of the last 50 years which indicates that the Southwest has just entered an extended dry period (see Figure 15) with little justification of the hope of a return to a long wet period within the next 50 years.

The Tradeoffs Arising from a Short Supply of Water

In view of the hydrologic and tree-ring records discussed above, it would seem imprudent for planners in the Colorado Basin states to make assignments of water up to the limit of the allocations arising from early estimates of the river's flow. Further, if the tree-ring record is to be believed, it may not even be prudent for planners to restrict themselves to conclusions based upon the entire historic hydrologic record and averages derived from that record.

For planning purposes, an advisable policy would be to use the procedure of Weatherford and Jacoby. That is, water planners could assume as a lower limit of river supply the average calculated from the tree-ring data (13.5 maf per year) and the upper level, the most optimistic view of the Interior's report (14.5 maf per year), as the range of possible supply.[55]

If a more careful examination of streamflow data shows that the lower level of supply arising from dendrochronology is the more realistic long-range average, then the pressure points arising from priorities in the allocation of Colorado River water to its many claimants will be greatly intensified.

The Lower Basin states are greatly dependent upon Upper Basin assignments of water to power projects producing electricity for the Lower Basin. This point, which is often overlooked, is illustrated in Figure 16, which shows the area served by electrical energy produced by the proposed Kaiparowits Project in Utah.

In view of the pessimistic outlook regarding water availability in the Upper Basin, future energy industrialization in the Upper Basin may not be able to depend on surface water for the production of energy in the present mode. There are several alternate paths for energy planners to consider: (a) the exploration and mining of deep ground water in the Upper Basin for the use of the energy industry; (b) exportation of coal and other fuel resources to markets outside the Basin for conversion to energy in plants also located outside the Basin; (c) the adoption of a technology that does not require water cooling for power production; and (d) the transfer of water from other uses. Of these four, the first alternative probably has the least severe economic and political consequences.

In the Upper Basin, if a water-based energy conversion technology is generally adopted by the power industry, a low level of flow in the Colorado River will force a choice between using the unallocated surface water for expanding food and fiber production, or for expanding the energy

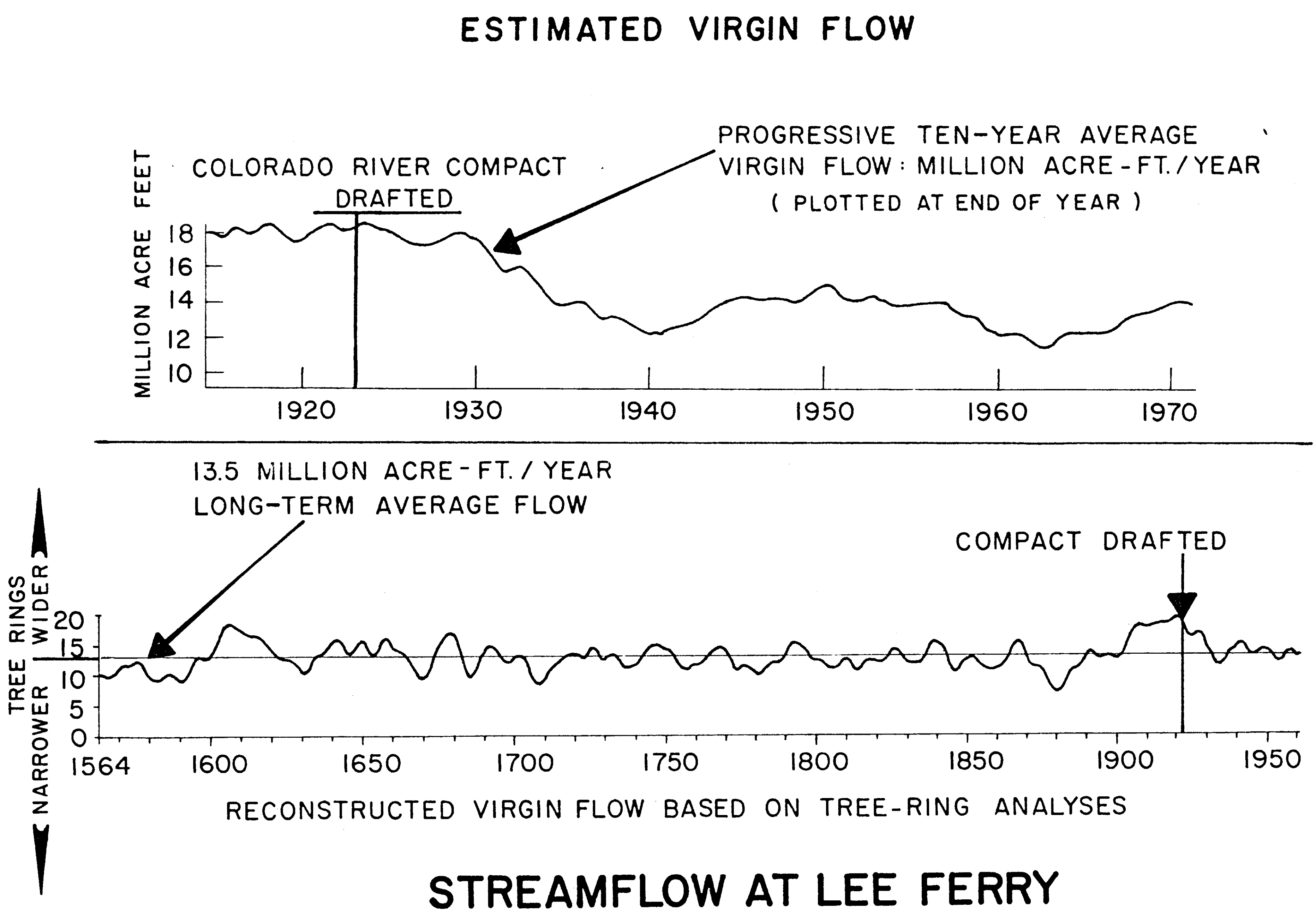


Figure 15: Flow of the Colorado River: A, Estimated Virgin Flow; B, Streamflow at Lee Ferry (Source: Reference 52)

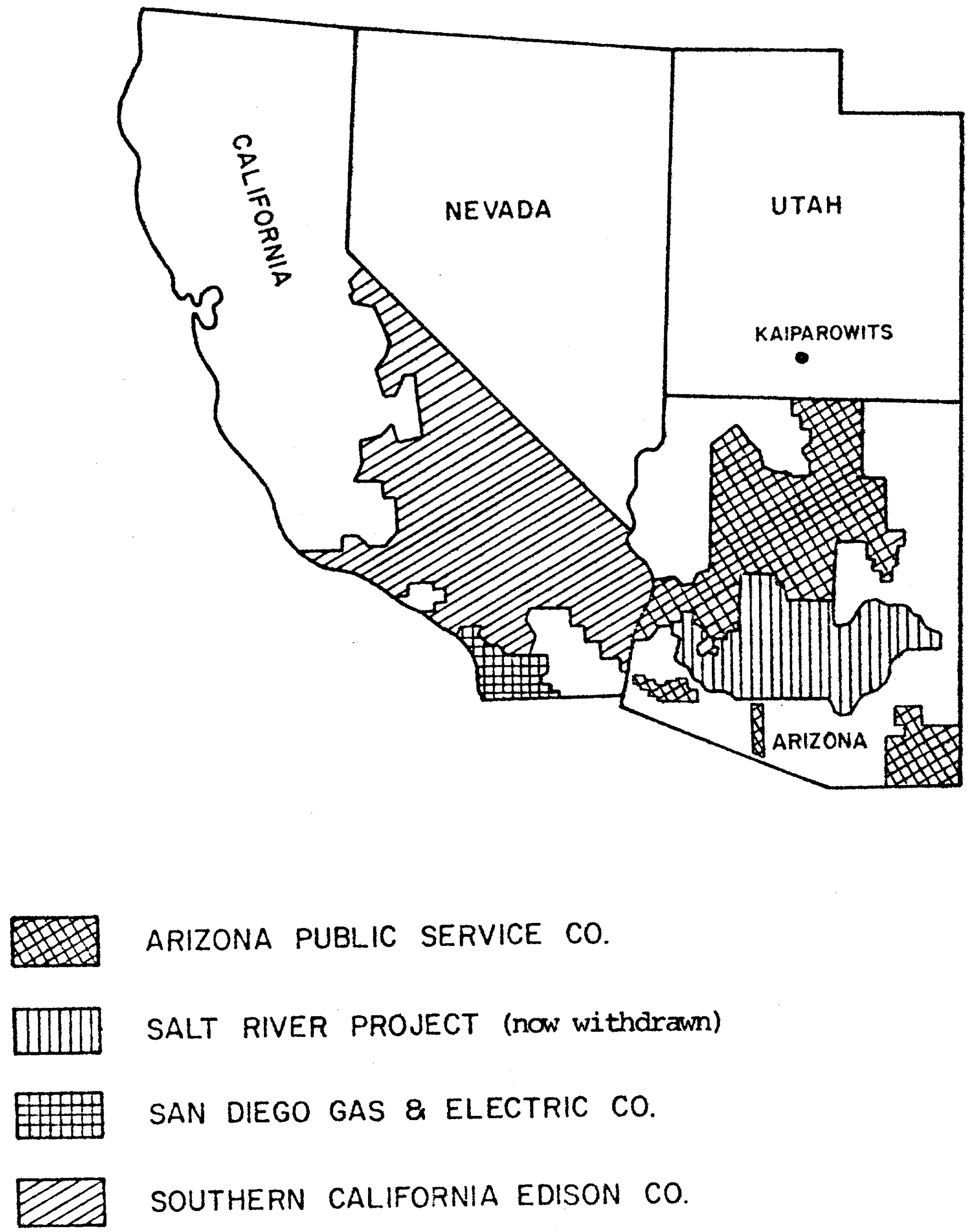


Figure 16: Kaiparowits Project Participants: Source Territories
(Source: Reference 35, page I-16.)

industry. The energy industry can afford to pay a large price for Upper Basin surface water, and new agricultural developments may be threatened with water shortage if water allocations are controlled by the market.

From the point of view of the Lower Basin, a shortage of water in the Upper Basin will intensify the pressure points on the Law of the River, and probably will force a resolution of ambiguities in definitions that give one part of the Basin or the other the advantage in allocation.

Surface Water of the Colorado River System for the Lower Basin States

If energy and agricultural developments in the Upper Basin continue as planned[56] and the amount of water flow is that projected by the pessimistic estimates, in two decades the Upper Colorado River Basin will be using all of the water available in its share for consumptive use. The pace of energy development of the Upper Basin will be a national issue, and the demand for such industrialization will be great. The Upper Basin states also have large demands for increased exports of Colorado River water west across the Wasatch Mountains, east across the Colorado Rockies, and southeast into the Rio Grande River Basin.

Facilities constructed under the Colorado River Storage Project have provided the Upper Basin with water storage capacity to enable storage during wetter periods for release during dryer periods. With the completion of the storage system in the Upper Basin, it is to be expected that effort will be exerted to prevent unnecessary spills into the Lower Basin during heavy runoff periods. That means that the Lower Basin states can expect intensified efforts on the part of Upper Basin states to utilize all the water to which they are legally entitled.

When the Central Arizona Project is completed and Upper Basin commitments of water are realized, California will have to begin cutting back from its present use of 5.4 maf per year to 4.4 maf per year. In California, the State Water Project bringing Northern California water to Southern California will compensate for the amount of water lost from the Colorado River. Even when Arizona is able to utilize the full share of the Colorado River water to which it is legally entitled, it will still be in a deficit water condition. Water consumption in Arizona will exceed supply from surface waters and the natural recharge into ground water aquifers within the State.[57]

All Basin states are very interested in the possibility of flow augmentation to the Colorado River because they are responsible under the 1922 Compact for delivery of Mexico's treaty allotment.[58] Flow augmentation is a possible way of securing that obligation and thus increasing the available water supply. There are two possible ways of increasing augmentation: (a) water importation from the Columbia River Basin, and (b) cloud-seeding (winter orographic snowpack augmentation). Jacoby,[59] as have many before him, concluded that augmentation from the Columbia River Basin was so unlikely that it is not a sound operational hypothesis for Lower Basin water managers.

Jacoby also concluded that even if augmentation from cloud-seeding were effective, it is likely that any increased flow would be used up by Mexico's allotment. Second priority of augmented flow would go to the Upper Basin states, unless they were already receiving the same amount of flow as the Lower Basin. Jacoby concluded that Lower Basin states should not rely on augmentation as an operational hypothesis to increase water usage.[60]

California's utilities have very meager prospects of finding the flexibility to assign water rights belonging to California's share of the Colorado River water for the use of coal-based powerplants outside the State (even though the power would flow to California). On the other hand, the assignment of water rights for coal-fired powerplants depends upon officials of states outside California who may find it in the best interest of their own citizens not to grant needed water rights from their states to California utilities. At the present time, a permit for 0.102 maf per year from Utah's allotment has been approved, but not yet perfected, to SCE for use by the Kaiparowits Project. This is one of the last large allocations of Utah's water entitlement. The approved amount of water would be sufficient for 6,000 MW of power production, although the present application before the Secretary of the Interior proposes a 3,000-MW plant. At the Kaiparowits site, the permit must be renewed in the late fall of 1975, since the water has not yet been used (that is, perfected). It appears unlikely that there will be sufficient unappropriated surface water remaining in Utah's allocation to support further permits of this magnitude for power production[61] elsewhere in the State. Under such circumstances, recourse to water-right transfers could be expected.

<u>Upper Basin Ground Water for Power Production</u>

Not all coal-based powerplants in the Upper Basin involving California utilities are based on the use of surface water. IPP, using LADWP for the engineering feasibility study and ICPA for water acquisition, has discovered a large flow of ground water near Caineville, Utah (see Figure 7 for the location). The ground water is in the Henry Mountains Basin. The following is quoted from the IPP booklet:[62]

> "It is estimated that the nominal 3,000 MW IPP project will require 50,000 acre-feet of water annually for cooling purposes.
>
> "To meet these water requirements, in the arid south-central region of Utah, ICPA undertook an aggressive and extensive program in 1971 to obtain an adequate water supply.
>
> "Applications were filed in the Caineville area for unappropriated surface and ground water to supply project requirements. The surface water would come from the Fremont River which flows through Caineville.
>
> "Favorable results have been obtained in connection with an ICPA test well drilled about 3-1/2 miles northwest of Caineville in Wayne County. During fall and winter 1973, the well was drilled to a depth of 760 feet, thus reaching 92 feet into the main Navajo Sandstone. Test pumping in this well in early February 1974 produced 7 cubic feet per second flow (approximately 1,000 acre-feet per year) and thereafter 3.1 cfs artesian flow. These results have prompted ICPA officials to describe this well as a 'major water find - possibly the largest in the State's history' [actually 7 cubic feet per second flowing for a year is about equal to 5,000 acre-feet].
>
> "A new IPP test well is currently being planned near the existing ICPA well in the Red Desert [west of Caineville]. This new well is planned to extend approximately 1,700 feet beneath the surface to the bottom of the Navajo Sandstone aquifer. The new well will provide additional data regarding the quantity and quality of the ground water and identify numerous characteristics of the aquifer."

Deep ground water in the Black Mesa Basin north of Flagstaff, Arizona, is presently used by a coal resources development concern. Water from this source is used to transport Black Mesa coal by slurry pipeline to the Mojave coal-fired plant in Nevada, which serves LADWP and SCE. This flow amounts to about 2,300 acre-feet per year.

A photograph of a clay model of the major structural basins of the Upper Colorado River Basin, constructed from the Tectonic Map of North America,[63] is shown in Figure 17. The surface of the model represents the elevation relative to sea level of the top of the Dakota sandstone, as taken from the topographic map. Of course, the earth's present surface does not conform to the top of Dakota, as it is deeply buried by younger rocks in many areas and has been eroded away in others. Also, the vertical relief is exaggerated in the model for clarity. The contours of the Dakota sandstone modelled in the photograph show a number of major structural basins in the Upper Colorado River Basin, of which seven are reproduced in Figure 16. Within each of these structural basins is a major coalfield, a major oil basin, or a major oil shale deposit. About 1,000 feet stratigraphically below the Dakota sandstone in the basins of southern Utah is the main aquifer, the Navajo sandstone, which was mentioned in the IPP report quoted above.

Figure 18 is a sketch of the structural basins taken from Figure 17. In Figure 18, major water recharge areas are also shown: for example, the Water Pocket fold and the San Rafael swell which are recharge areas of the Henry Mountains Basin.

The structural basins of the Colorado Plateau contain ground water in sedimentary rocks and fractured volcanic rocks. Discussion in this Bulletin is restricted to this type of ground water reservoir. There are other types of earth materials, however, such as unconsolidated materials (alluvium or gravel), which may serve as natural reservoirs for ground water. Water contained in alluvium within fault basins also is tapped in the Southwest, particularly in the Basin and Range Province, and while alluvial basins are important sources of water (especially in Arizona, Nevada, and western Utah), they are not available as a major water source within the Colorado Plateau Province which contains most of the Upper Colorado River Basin.

Ground water reservoirs can also be classified in terms of their size (whether they are local or regional in extent). Most aquifers in unconsolidated materials are localized because they are found in alluvial valleys, bounded by fault blocks. On the other hand, ground water reservoirs in bedrock, such as in the Navajo sandstone, can possibly extend tens and hundreds of miles.

Ground water divides, analogous to drainage basin divides on the land surface, separate ground waters of one basin from those of another. Often, ground water divides can be moved by an exceptional extraction of ground water from one side of the divide. Thus, the hydrologic highs will correspond only approximately to the saddle points of basins, demonstrated in Figure 18.

The important deep aquifers of the Colorado Plateau are the Navajo, Entrada, and Wingate sandstones. Of these, the Navajo sandstone forms the best aquifer because of its unusual microscopic structure. It is composed essentially of rounded grains of quartz, cemented by quartz or in some cases calcite (calcium

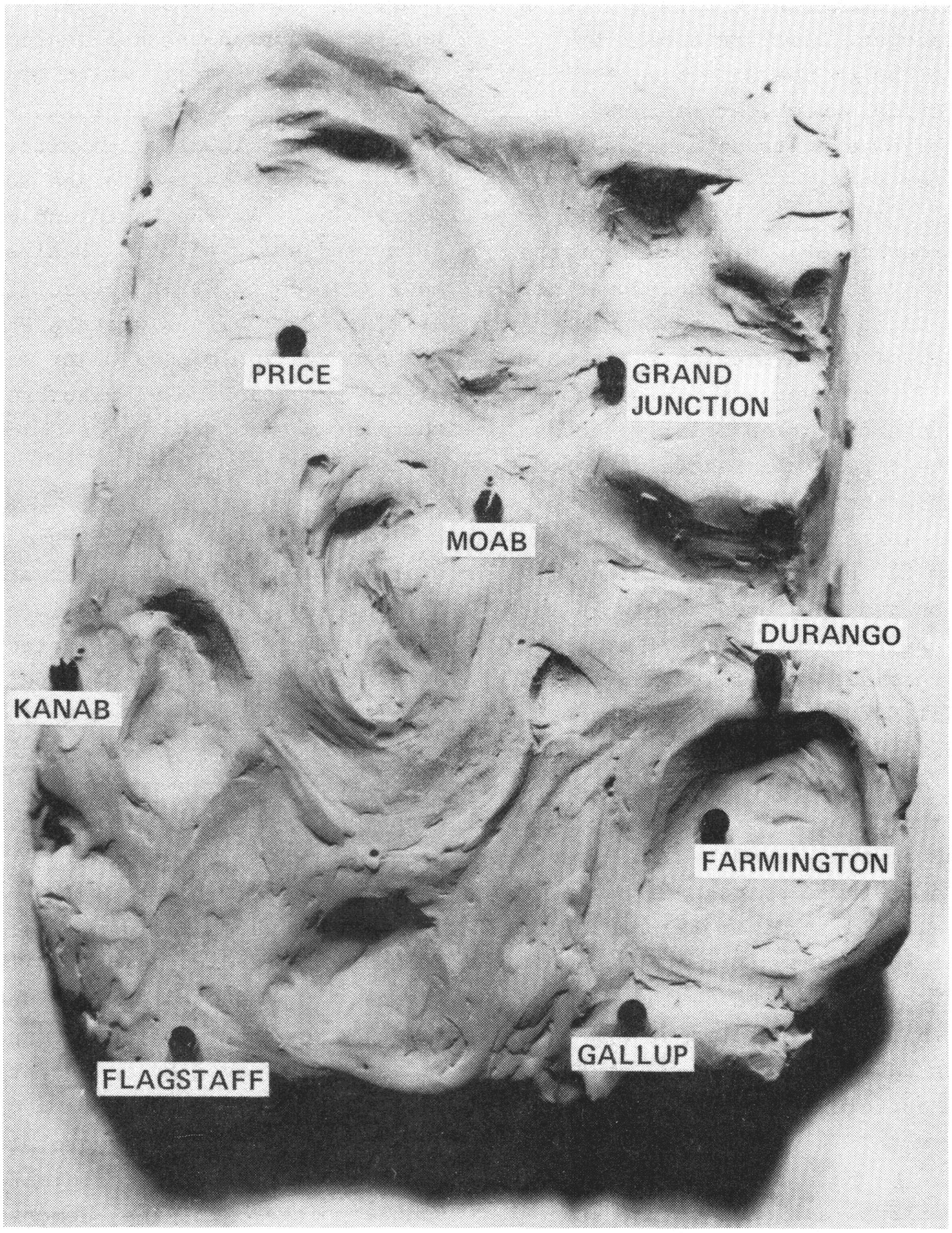


Figure 17: Clay Model of Structural Basins in the Colorado Plateau Province

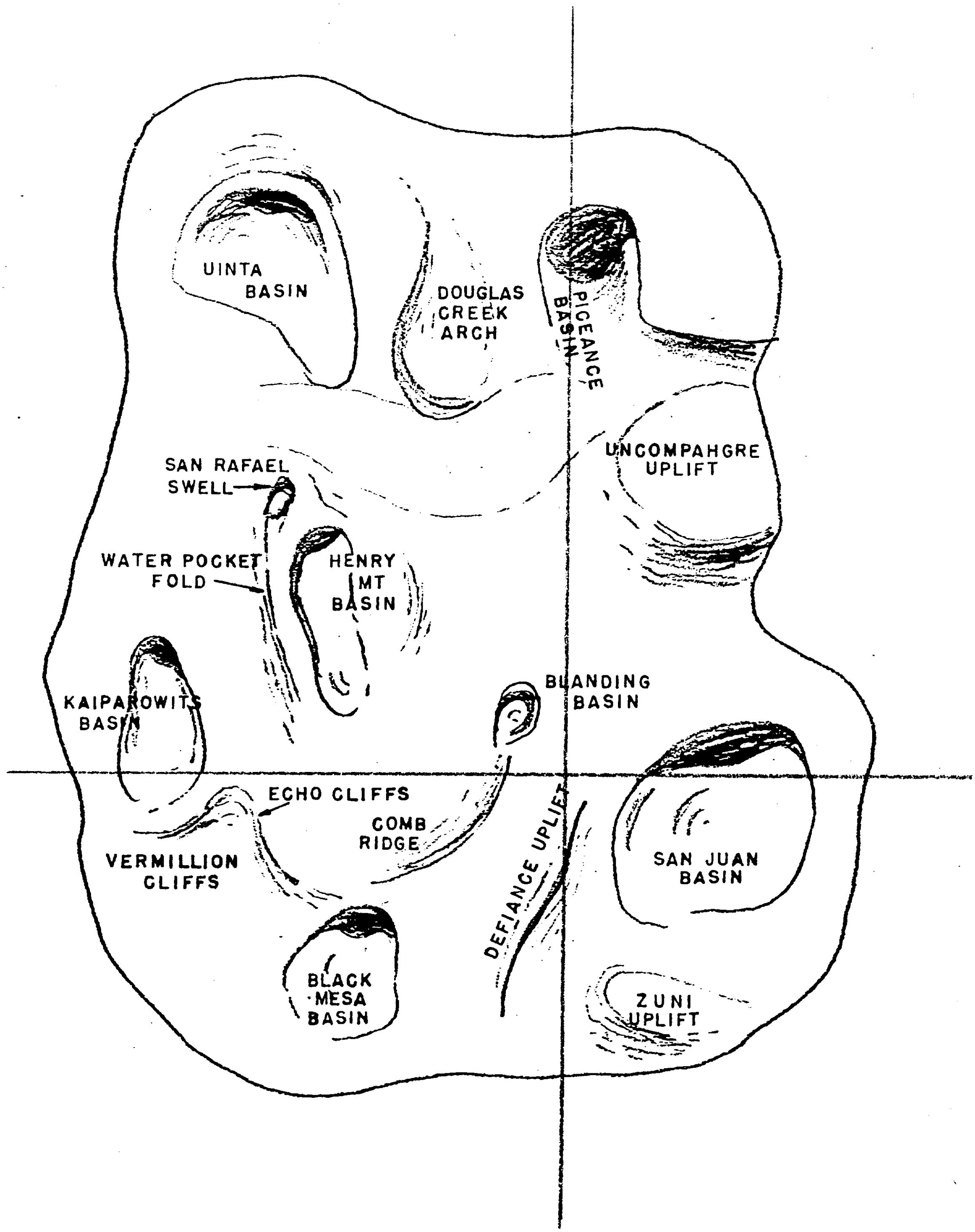


Figure 18: Structural Basins and Recharge Areas in the Colorado Plateau Province

carbonate). On a microscopic scale, Navajo sandstone is porous. The void space of Navajo sandstone is typically high, amounting to 15 to 30 percent (25 percent is the typical porosity). The voids are interconnected so that the sandstone is highly permeable (water flows easily through it).

Most of the basins in Figure 18 could conceivably contain large ground water reservoirs, because the sedimentary beds surrounding each basin dip inward toward the basin center. Thus, water entering the rocks at the basin margins presumably percolates slowly down the dip of the sedimentary formations toward the bottom of the structural basin. Aquifers in the center of basins have been filled slowly over geologic time.

In many cases, these aquifers lie at rather large depths (from 2,000 to 5,000 feet) below the surface. While little attempt has been made to prove by drilling that the basins are filled with water, there appears to be no geologic reason why the Navajo sandstone aquifers in the bottom of the basins should not be filled. The volume of Navajo sandstone in the lower part of the basins is so large that they could hold tremendous amounts of ground water. A basin 50 miles wide (assuming the aquifer to be 1,000 feet thick and to have a porosity of 25 percent) could contain several hundred million acre-feet of water. Goode[64] estimated that there is about 20 maf of deep ground water in the Navajo sandstone of the Kaiparowits Basin and that about half of that amount should be available for development from depths of less than 400 feet.

It is important to note that the potential of these groundwater reserves will be affected by possible slow delivery rates or by adverse water quality. Basins with thick sections of Cretaceous or Tertiary rocks, such as the Piceance Creek and San Juan Basins, will probably have saline water.

The recharge areas (exposed Navajo sandstone with the appropriate dip) surrounding the basins are quite large (especially those surrounding the Henry Mountains and Kaiparowits Basins). The basin's annual recharge rate equals the aquifer's exposed area multiplied by an appropriate fraction of the rainfall. Exposed volcanic rocks often change this computed recharge.

Some of the ground water in the Navajo sandstone in the Upper Colorado River Basin drains to and helps support the flow of the Colorado River and its tributaries. In these instances, large withdrawals of ground water would adversely affect the surface water flows. Consequently, there are legal constraints in the large-scale development of ground water.[65] The Kaiparowits Basin and the Henry Mountains Basin appear to have minimal connection between ground water and the surface water supply of the Colorado River System.

<u>Ground Water Supplies and Agricultural Waste-Water in Southern California</u>

Ground water resources in the Southern California desert regions--especially the Colorado Desert and the South Lahontan hydrologic study areas--are little known.[66] Since most of the population lives in the south coastal district, most of the attention of hydrologists and engineers has been focused on the ground water resources in areas near the ocean.

It is in the South Lahontan and the Colorado Desert districts, however, that one must look for new water resources to accommodate any coal-fired powerplants if they are to be built in the desert regions of Southern California.

While Californians do not want the air quality problems associated with coal-fired powerplants in their state, and while at present Southern California utilities are finding accommodation with Utah officials for the building of coal-fired powerplants in Utah, it would seem prudent to be prepared for any contingency. Towards this end, systematic exploration and measurement of ground water in the deserts of Southern California should be encouraged. It is important to know if the surface water of California can be supplemented by significant amounts of ground water from the desert regions of California.

The disposal of agricultural waste-water is a serious problem for several irrigation districts in Southern California. The use of this irrigation waste-water for powerplant coolant water could alleviate the restricted water supply situation. There has been considerable progress made in this area, and research centered on this possibility should be encouraged.

A Research Program for Finding Additional Ground Water Resources

The necessary research program for finding deep ground water in the Colorado Plateau would consist of an attempt to assess the extent of the quantity of water in a particular basin, and to estimate the annual recharge into that basin. Systematic studies should be done of several basins in the Colorado Plateau Province. Of special concern to Southern California utilities are the quantities of water in the Kaiparowits and Henry Mountains Basins.

Preliminary work would consist of measuring the volumes of the basins and the size of recharge areas, using geologic maps and field observation. Analytical and experimental research would consist of inventing methods to estimate the depth of the deep ground water table, using remote-sensing techniques. Field programs would consist of drilling deep wells to prove the existence of ground water and of performing pumping tests to measure the rate at which the ground water reservoir would be diminished by a given pumping rate.

California energy planners, as well as those in national offices, should do all they can to promote research and exploration aimed at uncovering deep ground water resources in the Upper Colorado River Basin. A recent publication by the USGS indicates there is generally little detailed information available about deep ground water reserves in the Upper Basin[66] (except about ground water reserves on the Navajo and Hopi Indian Reservations[67]). The stakes are high for Southern California as well as for the Upper Basin states. If the coal resources of the Upper Colorado River Basin are to be used as a major way of producing significant amounts of energy for the Southwest, then it is important to know if the surface water resources of the Upper Basin can be supplemented by significant amounts of ground water.

One of the important public issues which needs to be resolved is the question of the legal status of the ground water in various basins. It is important to determine whether the ground water is connected to the surface water system of the Colorado River drainage. If it turns out that the ground water is not connected with the surface water of the Colorado River, then a case can be made that this water is not subject to the Law of the River.

Refinement of geochemical methods of distinguishing between ground water in the Navajo sandstone and Colorado River surface water will be important for this purpose. Research applications in this area should be encouraged, especially those which disclose resident time of the ground water. Reynolds et al.[68] have analyzed the major element geochemistry of Lake Powell and its immediate tributaries, and their work could be the basis of the needed new study.

The strategy of finding ground water reservoirs in the alluvial basins of the Southern California desert would be quite different. In this case, methods appropriate to locating and quantifying water in the valleys in the Basin and Range Province would be utilized.

AIR POLLUTION IN SOUTHERN UTAH RECREATION LANDS

The Destruction of Air Quality

Producing energy for Southern California by burning coal in Utah has many advantages for Californians. In an area where smog is a daily concern, there is little desire among either residents or officials to raise the levels of air pollution by establishing coal-fired powerplants in the Los Angeles Basin or its vicinity.

Forces in Utah are mobilized to build coal mines and to construct powerplants in southern Utah. These mines and powerplants will be established in an economically depressed area in which many residents welcome this new industry as a way to ease a number of social and economic problems.

The creation of large powerplants in southern Utah for the production of power for Southern California would therefore appear to solve major problems in both Utah and California. Indeed, the establishment of the proposed powerplants is an example of a trade pattern of the two states that has many historical parallels.

Unfortunately, the proposed location of the Kaiparowits powerplant is not merely a remote desert, but is a very special desert centered in a unique recreational and wilderness region which is appreciated by visitors from the rest of the United States and the world.

The coal reserves of the Kaiparowits Plateau are surrounded by six National Parks (Grand Canyon, Zion, Bryce, Capitol Reef, and Canyonlands) and by the Glen Canyon National Recreation Area. Arches National Park is nearby. A plume from the stacks of the proposed plant could reach any one of these areas. In addition, the Kaiparowits Plateau is not far from a number of National Monuments, as well as famous scenic regions like Monument Valley (Figure 19). The frequency of the plume

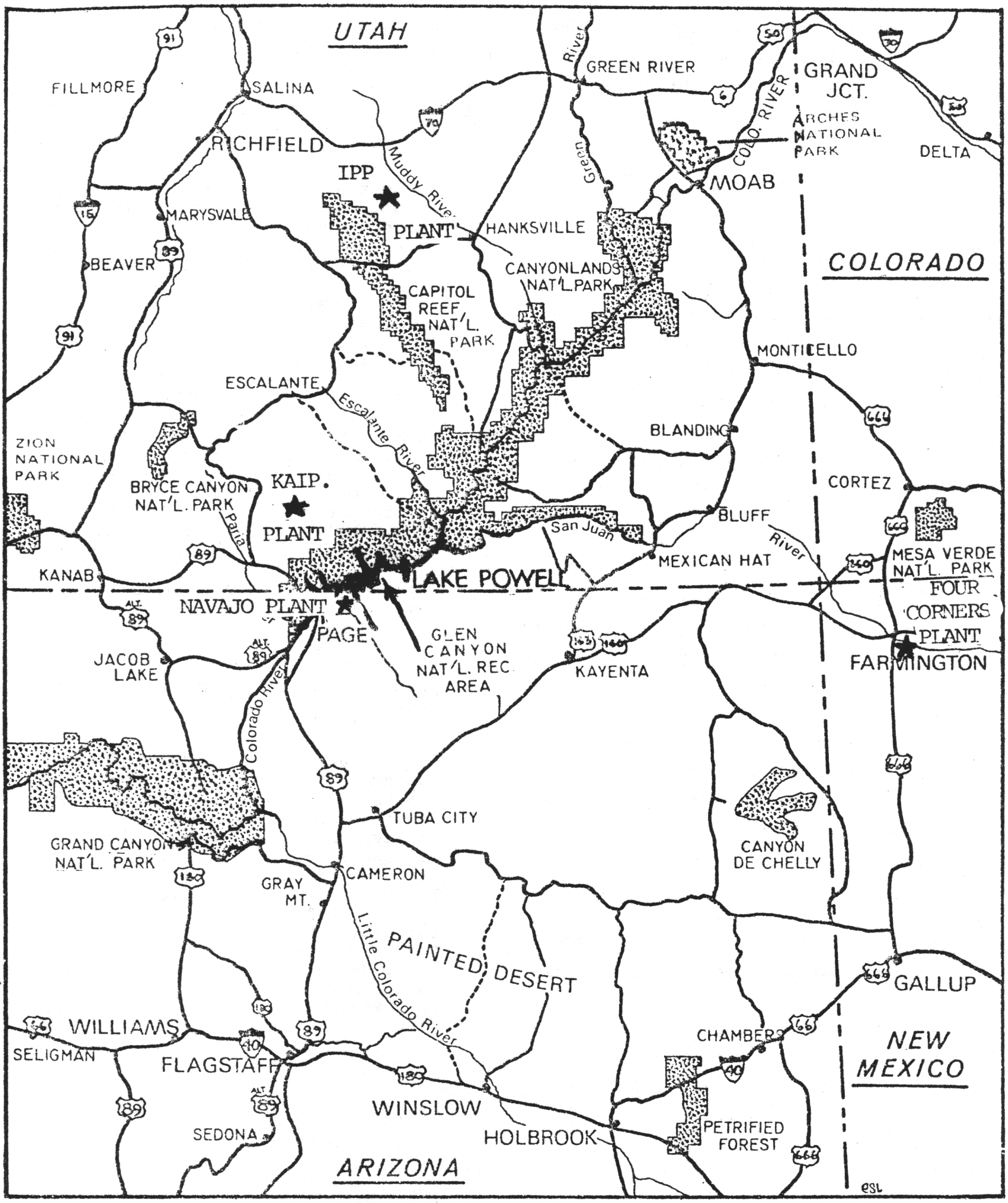


Figure 19: National Parks, Monuments and Recreation Areas, Four Corners Region (Source: Reference 54, page

reaching any area depends on wind direction. The magnitude of the impact of the plume on air quality characteristics such as visibility depends on the amount of pollution emitted, atmospheric stability, wind speed, and the characteristics of the powerplant stack.

The present air quality of this region has been carefully measured; the air is reported to be among the cleanest and quietest in the United States.[69] The recreational experiences of millions of people who annually visit Grand Canyon National Park and neighboring National Parks depends greatly upon the renowned purity of the air.

With the construction of extremely large coal-fired powerplants in the center of this great recreational mecca, there are two questions which should be addressed: What will be the impact of this power development on the air quality of the region? What will be the reaction of the public at large and of local citizens to the change in air quality resulting from power development?

Great efforts have been made by SCE to ensure that emission levels of the pollutants from the proposed Kaiparowits Plant will be at a far lower level than from powerplants constructed previously in the region (such as the Four Corners Plant). While these efforts to control emission are substantial, the amount of effluents will be large because of the enormous quantity of coal to be burned. (The 3,000-MW plant operating at full capacity will consume about 33,000 tons of coal per day and will produce 2,440 tons of fly ash per day.)[70]

The visual impact of the effluents from the proposed Kaiparowits Plant has been described in the Kaiparowits Draft EIS.[71]

> "Potentially, the most severe visual impact to the area, and possibly to the entire region, could be pollution created by smoke and other airborne particles emitted from the plant.
>
> "First, the distance one can see would be substantially reduced... Visibility in the scenic region of southern Utah and northern Arizona could be reduced 10-20 miles, which would be an adverse effect on the viewers' perception of the open characteristics of the landscape and a negating of the more distant topographic features. A study [Bechtel Power Corporation] sponsored by the participant indicates the reduction of visibility of this magnitude [i.e., 10-20 miles] would occur infrequently.
>
> "Second, coloration of pollutants could alter the natural coloration of blue sky and particularly affect the contrast of scenic topographic features against the skyline. The degree of impact would depend on the viewers' position in relation to the plume.
>
> "Should any of the pollution control equipment malfunction there would be a possibility for severe visual impacts. There would be a good possibility that dense visual air pollution would drift into outstanding scenic areas such as: Bryce Canyon National Park, Glen Canyon National Recreation Area, Dixie National Forest, Kaibab National Forest, Grand Canyon National Park, Zion National Park, Capitol Reef National Monument [now a National Park], Monument Valley, and other highly scenic areas."

There are other manifestations of the impact of power development on the air quality of southern Utah in addition to those described above. In response to the Kaiparowits Draft EIS, M. D. Williams pointed out that the projected emissions from the proposed Kaiparowits Plant combined with the existing Navajo Plant nearby would amount to 234 tons per day of SO_x and 446 tons per day of NO_x, assuming that the control equipment functions as designed.[72] He pointed out that this would amount to 53 percent of the Los Angeles Basin emissions of SO_x and 30 percent of Los Angeles Basin emissions in NO_x. Williams concluded that if the plume from the plant reached Bryce Canyon National Park, the levels of NO_x in the Park could exceed the present adverse levels in California.[72]

Fallout of Chemical Contaminants

There are three mechanisms by which air contaminants produce effects within a region. The first mechanism is modification of the atmosphere's ability to transmit light, which has been discussed above. In addition, there is the direct impact of ground level concentrations of contaminants on materials, plants, animals, and humans. The third mechanism is the deposition of materials on surfaces which produces changes in the medium beneath the surface.[73]

There are several potential adverse consequences which should be evaluated. Of some concern is the rate of phosphorus deposition to be expected on Lake Powell, because phosphorus could increase the biological productivity in the lake. Deposition of contaminants could locally damage the productive capacity of soils. In addition rain made more acidic by emissions might harm the vegetation, especially forests at high altitudes. A more detailed discussion of these problems is found in Williams and Walther.[74]

Reaction to the Destruction of Air Quality

It appears that the presently clean air of the Kaiparowits region is bound to be polluted to some extent by construction of the Kaiparowits Plant. This may violate the provisions of the Federal Clean Air Act of 1970 and particularly the "nondegradation clause" designed to protect pristine airsheds.

There is currently little indication that the construction of the Kaiparowits Plant would be significantly impeded by the Federal Clean Air Act of 1970. Local environmental resistance to the construction of this plant in Utah is mild compared, for example, to the local resistance rising against the construction of nuclear plants in Southern California. Potential environmental resistance is just over the horizon, however.

In a court action introduced in Sierra Club v. Ruckelshaus,[75] it was held that the quality of air must be improved, not degraded.[76] This has been interpreted to mean that air quality may not be allowed to deteriorate significantly in states where the air quality is now better than the national secondary ambient level.[77]

EPA regulations in response to this decision call for the establishment of three classes of standards applicable to different areas. Class I is applied to areas in which practically any change in air quality would be considered significant.[78] All areas of the country initially were designated Class II, and redesignation may be proposed by the respective states, Federal Land Managers, and Indian governing bodies.[79] The control of such a redesignation can pass to the Federal Land Manager of National Parks and National Forests, who can elect to keep the air quality over the Federal lands in a more pristine condition than a state may designate.[80] A successful action by a Federal Land Manager to designate as Class I any of the surrounding National Parks

(Grand Canyon, Zion, Bryce Canyon, Capitol Reef, Arches, Canyonlands) or the Glen Canyon National Recreational Area probably would hinder the construction of the Kaiparowits Plant or the IPP Plant.

It is also possible that construction of a plant could proceed and later be impeded. Looking further into the future, it is quite possible that the effects of pollution resulting from a plant once built and in full operation will create an environmental furor and second thoughts among the local citizens of Utah. In this event, an environmental battle on the national level concerning the protection of the National Parks and Monuments can be expected. A pitched environmental battle over the issue of reducing the pollution might prohibit new plant construction and/or expansion of existing powerplants in Southern Utah.

At such a future time, California may no longer be urging the expansion of coal-fired facilities for generating power. The population in Southern California may not have grown sufficiently to require additional capacity in utilities as is presently projected. In fact, forecasts of demand now predict diminishing energy requirements. Another possibility is that abundant oil supplies may be available from offshore oil production and from the Alaska pipeline. In addition, restrictions concerning the siting of nuclear plants in Southern California may be eased.

On the other hand, none of these events is assured, and Southern California could continue beyond 1985 to seek increased electrical production from coal. Other futures can be equally well projected in which: (1) a large influx of people move into California from the colder regions of the country, (2) offshore oil adjacent to its coast may not be available for extensive use within California, (3) national legislation may divert most of the Alaskan oil to the eastern regions of the United States, and (4) there may be a moratorium on nuclear powerplants due to hazards of one sort or another.

Planners in Southern California must consider various alternative futures. Southern California should anticipate a contingency in which the State's utilities will make demands on Utah coal deposits beyond the present commitments for the Kaiparowits and the IPP Plants for electricity to be used in Southern California.

As the Kaiparowits Project becomes operational, new coal mines will be developed and a new town will be established for the people who will operate the required mines and the powerplant. Workers in the new town will be paid for mining coal and for operating the powerplant. However, the number of workers in the latter category will be small compared to the former. The financial base of the community will arise mostly from coal mining. Other coal mines, not owned by the power project, may open nearby and new markets may be sought for this additional coal.

If State officials and local residents of Utah become disenchanted with the process of coal development because of resultant air pollution from the burning of coal in the Kaiparowits Plant, or if Federal Land Managers secure a designation of Class I for the National Parks, then Utah officials may seek ways to have the coal mined but not burned in southern Utah. Should this happen, and should Southern California desire more coal-fired power to satisfy its demands for energy, then California utilities may decide that their best choice is to buy Utah coal, import it, and burn it either within the boundaries of the State of California or out at sea, using plants operated on special ships away from the land. (Alternate choices might include burning Alaskan coal.) It is for these reasons that California has a vital interest in the adoption of the most stringent air pollution controls in the Kaiparowits and IPP Plants.

A mechanism for California State agencies to require disclosure of out-of-State potential environmental impacts apparently now exists. Attorney General E. J. Younger issued an opinion concerning the applicability of the California Environmental Quality Act (CEQA) to a proposed power-generating plant (the IPP Plant) in Utah to be built jointly by a number of cities in both California and Utah.[81] Mr. Younger's conclusions are:

> "1. The CEQA applies to the whole of a project including those parts of a project occurring beyond the boundaries of a state.
>
> "2. Each 'responsible agency' must likewise consider the whole of a project including those parts occurring beyond the boundaries of the state, when each such agency is determining to carry out the project."[81]

TRANSPORTATION AND COAL COMMUNITIES IN SOUTHERN UTAH

Existing Transportation in the Kaiparowits Region

It is well known that improvement in transportation facilities can produce social changes. Once an important transportation facility has been introduced into a region, labor specialization, integration of the local economy into regional and national trade systems, and mobility of capital and labor generally result. Local customs and beliefs are replaced by cosmopolitan customs and beliefs. Conversely, a region which is not traversed by major transportation facilities tends to become insular, and to survive it must become more self-sufficient than neighboring regions which benefit from important transportation corridors. The location of many western cities was determined by the choice of railroad routes. Other areas far from the railroads have remained isolated and undeveloped until recent years.

The Kaiparowits region has been bypassed by the transportation corridors of the west. No railroads or superhighways traverse this region. Very few paved roads exist, and many of the unpaved roads are treacherous during the rainy seasons. Merchants in the town of Escalante, located in Garfield County adjacent to the coalfields of the Kaiparowits Plateau, must import produce from Salt Lake City in their own trucks, since jobbers do not find it profitable to make regular deliveries to Escalante. The paved roads of the area encircle but do not cross the Kaiparowits region. They are heavily used by recreationists seeking to enjoy the many National Parks, National Forests, National Monuments, and other recreational areas which surround the Kaiparowits Plateau.

The existing railroad network in the Southwest is shown in Figure 20. Of particular interest is the Rio Grande Railroad, which serves the coalfields of eastern Utah near Price. Coal towns shown

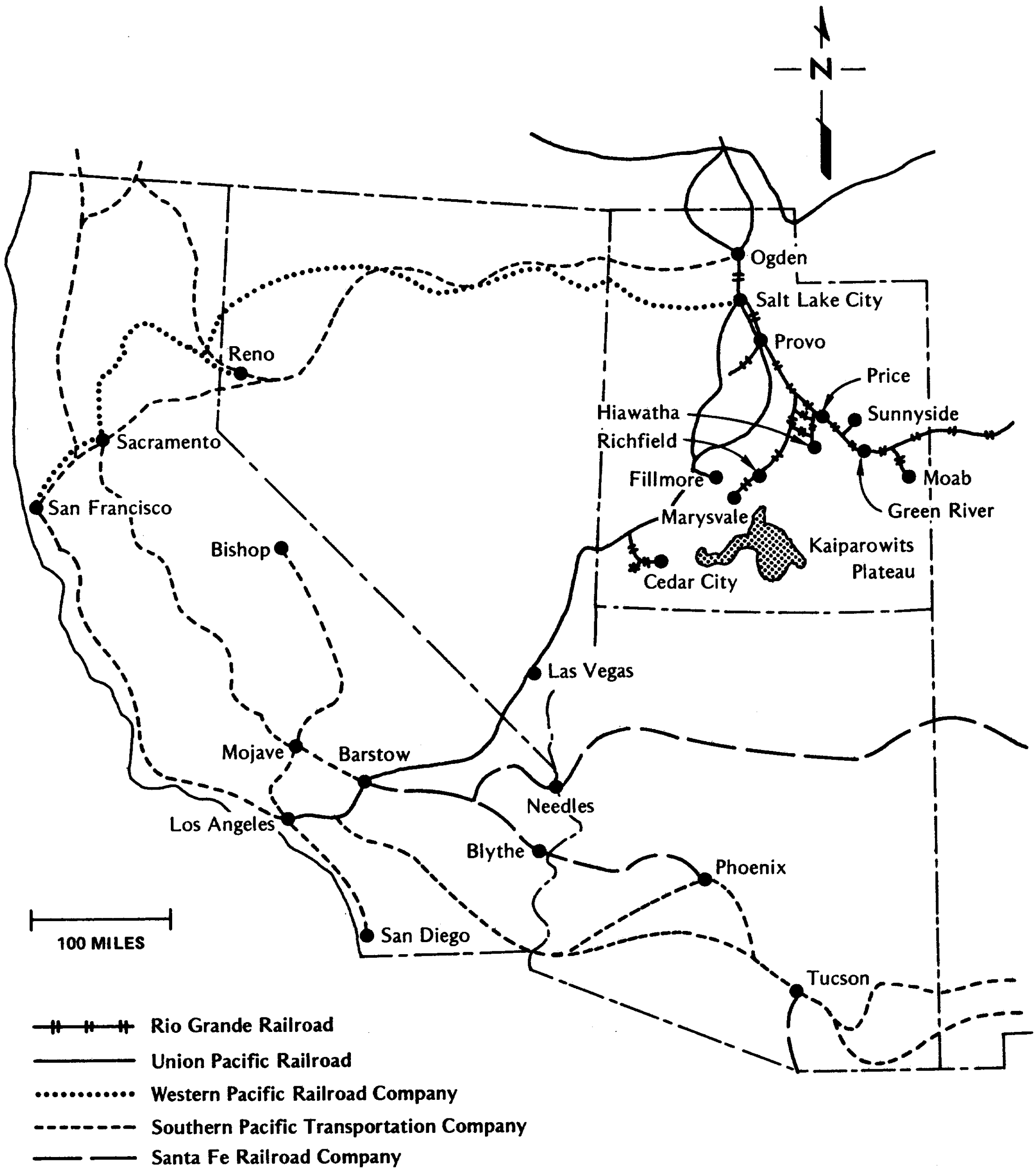


Figure 20: Railroads of the Southwest

in Figure 20 are Hiawatha and Sunnyside. A spur of the Rio Grande Railroad (actually the Utah Railway Co.) leads to Marysvale, where the chief originating traffic is uranium ore. It is seen here that the possibility exists for the construction of a railroad link north from Kaiparowits to the Rio Grande Railroad, or west to the Union Pacific Railroad. If such a connection were made, coal from the Kaiparowits could then be transported by rail to markets in a wide area of the Southwest.

The network of roads into and out of the Kaiparowits Plateau is presently meager. Utah Highway 89, between Kanab, Utah (population 1,795), and Page, Arizona, passes along the southern boundary over the Paria Plateau (Figures 21 and 22). Utah Highway 12 runs east of Bryce Canyon, skirts the northwestern side of the Plateau, passes through Escalante (population 644), and ends in Boulder (population 94). An unpaved road leads north from Boulder going around Boulder Mountain, and finally crosses the Capitol Reef National Park. Another unpaved road leads north from Escalante, crosses over the Aquarius Plateau, and ends in Marysvale. An unpaved road connects Escalante and Hole-in-the-Rock, passing parallel to the Straight Cliffs, which form the northeastern boundary of the Plateau and terminate at Lake Powell. An unpaved road between Escalante and Glen Canyon City traverses the Kaiparowits Plateau. Another unpaved road passes through Cottonwood Canyon, connecting Highway 89 just west of Glen Canyon City with Highway 24 near Cannonville (population 115), the road defining the western boundary of the Kaiparowits Plateau. Jeep trails abound in the region, but many areas are completely impassable due to the ruggedness of the canyon country. The paved roads are shown in Figure 22.

There are no gas or oil pipelines in southern Utah except for a minor incursion of an El Paso Natural Gas Co. line across the State boundary near Aneth, Utah, far to the east of the Kaiparowits region.

The only transportation links from the Kaiparowits region that can be considered well developed are the corridors transporting electrical energy from the region of Glen Canyon Dam. Plans exist to expand these corridors by major additions of new transmission lines from the Kaiparowits Plateau (Figure 8).

Coal Transportation in Utah

There are two large railroad lines in Utah, the Union Pacific Railroad and the Rio Grande Railroad. The construction of the Union Pacific Railroad, completed in 1869, was a national enterprise supported by Congress to provide the transcontinental link between the east and the Pacific coast. It crosses northern Utah because the national east-west corridor was chosen to follow the 38th parallel. The Rio Grande Railroad (formerly known as the Denver and Rio Grande Western) linked Salt Lake City to the rich coal mines of Carbon and Emery Counties in the early 1880s, and coal transportation is still a major source of revenue to this line. The main route of the Rio Grande crosses the Colorado Rockies and the desert ranges of northeastern Utah.

The importance of coal to the Rio Grande Railroad is shown in Table 5.[82] Here we see that the tonnage hauled of

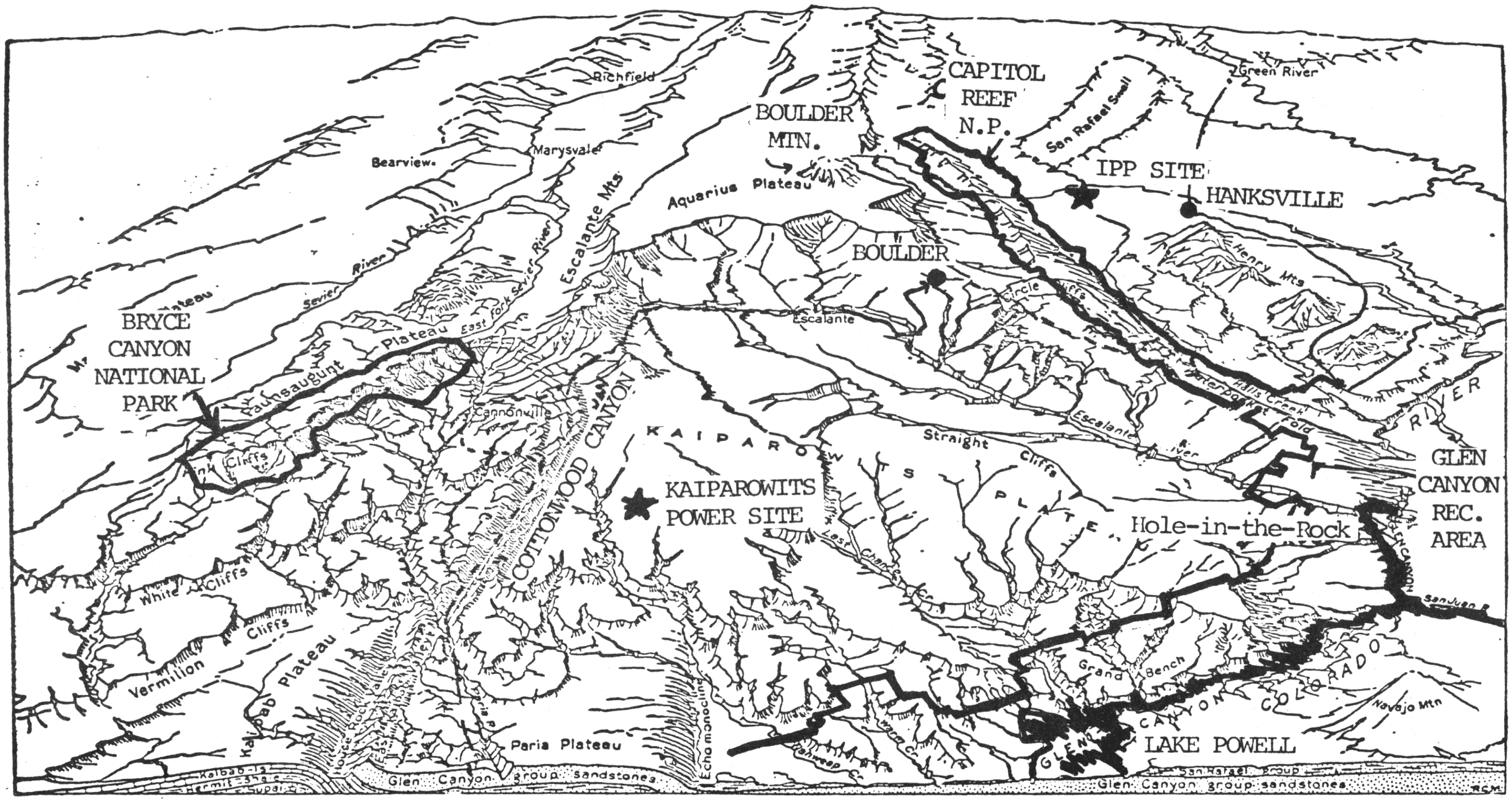


Figure 21: Generalized View of the Kaiparowits Region Looking North from the Utah-Arizona Boundary Line (Source: Reference 29, page 70)

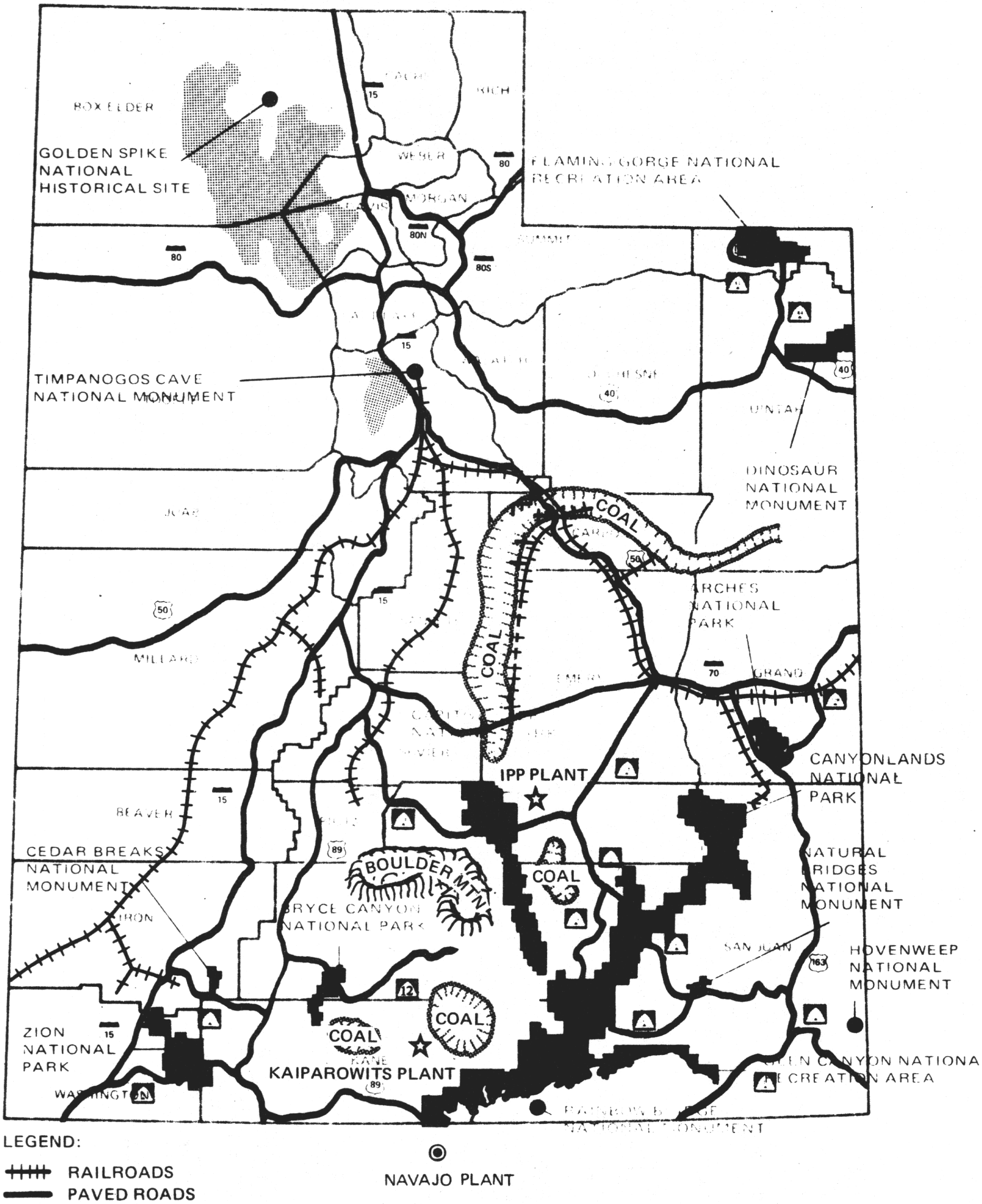


Figure 22: Railroads, Paved Highways, and Major Coalfields in Central and Southern Utah (Source: Modified from Reference 83, Figure A-2)

Table 5: Leading Commodities Origination--
Denver and Rio Grande Western Railroad, 1956

Commodity	Tonnage		Percent of Total	
Mine	9,219,914		100.0	
Bituminous coal		6,268,264		67.9
Fluxing stone		1,141,988		12.4
Lead etc., ores		622,216		6.8
Coke		174,036		1.9
Agriculture	345,103		100.0	
Sugar beets		168,083		48.7
Potatoes		45,086		13.1
Wheat		37,823		11.0
Peaches		19,323		5.6
Animal	136,982		100.0	
Cattle		55,973		40.9
Sheep		48,953		35.7
Forest	208,770		100.0	
Lumber, etc.		157,555		75.6
Pulpwood		46,532		22.3
Manufactures	2,149,257		100.0	
Steel		831,863		38.7
Cement		161,769		7.5
Wallboard		145,752		6.8
Copper		135,754		6.3
Sulphuric acid		122,313		5.7
Total	12,060,026		100.0	

bituminous coal was roughly half of all commodities in 1956. Furthermore, the bulk of the coal traffic flow in the railroad is captured in Carbon and Emery Counties and flows to Salt Lake for westward distribution (Figure 23). The coal exported from Carbon and Emery Counties is one of the three most valuable mining products of Utah.[83]

The Rio Grande has branch lines in Utah serving various communities in Carbon and Emery Counties. One branch serves the coal mines at Sunnyside and the town East Carbon. Other branches serve coal mines at Kenilworth, Rains, and Clear Creek. An extension of the Kenilworth branch has been proposed to extend to the town of Emery to link up southern Emery County coalfields. The network of rail lines serves almost all areas of the Book Cliffs and the Wasatch coalfields (Figure 11).

The Kaiparowits coalfield has abundant coal resources, comparable in both quantity and quality to the coal resources of Carbon and Emery Counties (Figures 11, 12, 13, Table 4). Why, then, is the Kaiparowits region so deficient in transportation and the mining of coal so neglected, while rail transportation is so well developed in the productive Carbon and Emery coalfields?

Any blame for lack of rail development in the Kaiparowits region cannot be levelled against the political and religious leaders of Mormon Utah. The Mormon Church through its policy of central planning and voluntary cooperation[84] was largely responsible for the economic development of Utah in the last half of the 19th century. It supported the construction of railroads in Utah, and even built some of its own.[84]

Furthermore, there was an aggressive policy to find iron and coal to support the overall economy. According to Arrington, "the town of Coalville, Utah was founded as part of a church mission to mine coal. Soon after the discovery of coal in 1859, it was being transported to Salt Lake City for church and commercial use."[85] The Mormon Church leaders built the Summit County Railroad in order to transport coal from Coalville to Salt Lake City, in competition with the Union Pacific Railroad which transported Wyoming coal to Salt Lake City at high rates.[86]

It is clear that the Mormon officials knew that extensive coal deposits existed near the town of Escalante on the Kaiparowits Plateau, because of the coal mines developed there before 1900. These mines provided fuel for the town of Escalante and surrounding communities until they were closed down. Their failure has been due to the preferential use of petroleum products instead of coal in the local towns.[87]

It is quite likely that extensive transportation facilities in the Kaiparowits region were never built because such an enterprise was too formidable, even in the days when competitive eastern capitalism was at its peak, and rails were being

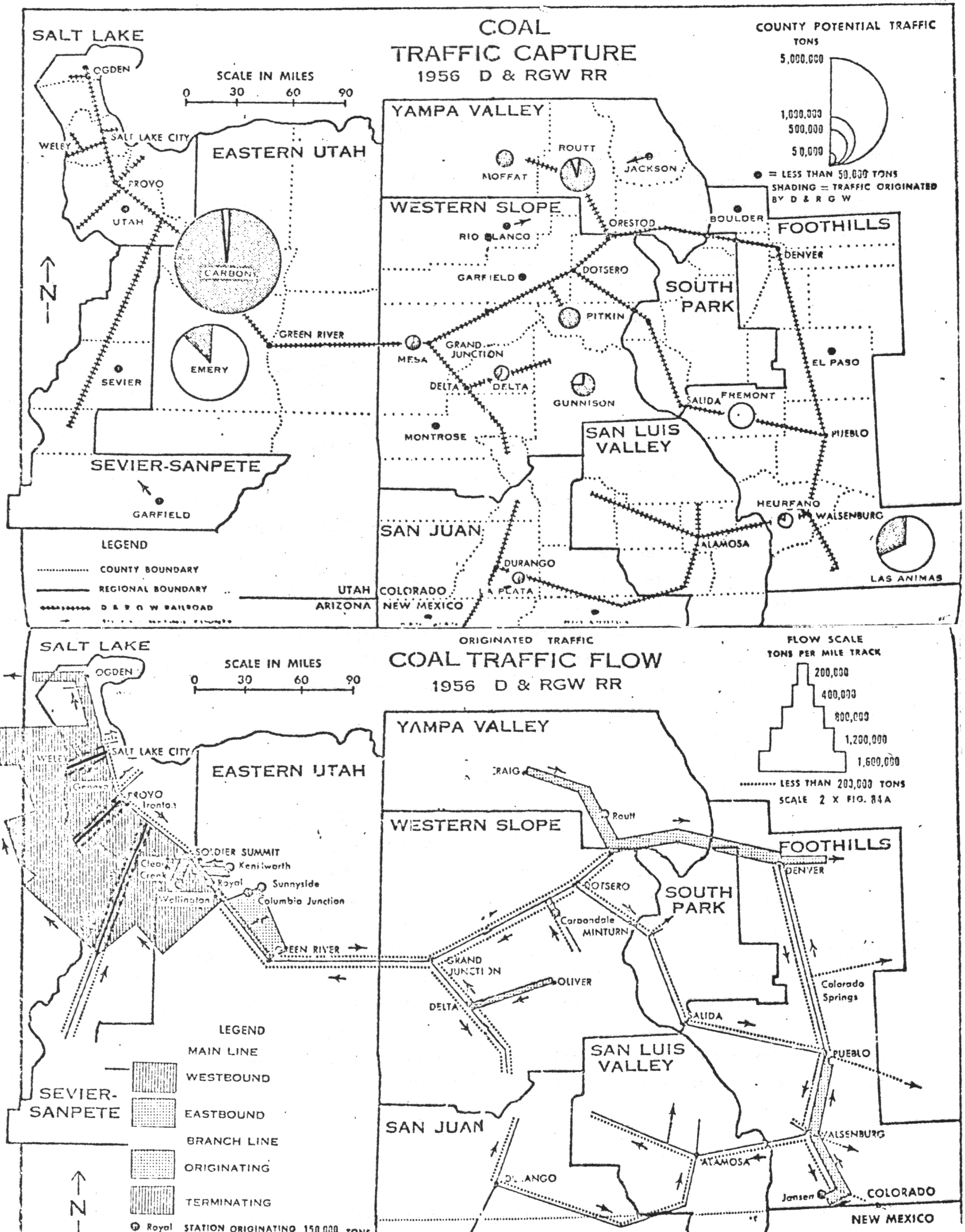


Figure 23: Coal Traffic Capture and Flow on the Rio Grande Railroad, showing the Importance of Coal from Carbon and Emery Counties, Utah (Source: Reference 82, pages 150, 151, Figures 66,67)

laid up nearly every canyon in Southwestern Colorado to exploit lumber, silver, and gold resources.[88]

The Physiographic Setting of the Kaiparowits Plateau

The Kaiparowits region comprises part of the Canyonlands Province of the Colorado River system, and part of the High Plateau Province of Utah. Formidable cliffs define the boundaries of the Plateau. The surface of the Plateau cannot be easily traversed because it is intricatly dissected by canyons. Great physiographic barriers exist between the Plateau and markets for Kaiparowits coal. Additional barriers now exist because National Parks and National Forests surround the Kaiparowits Plateau. Demands for preservation of these national reserves are checkpoints in the approval of new transportation corridors.

On the other hand, the coalfields of Carbon and Emery Counties were more accessible to economic markets because by comparison the terrain is less rugged, and the deserts in these counties offer an easy corridor between Salt Lake City and Denver.

The grandeur, the desolation, and the isolation of the Kaiparowits region have been described by Gregory and Moore:[89]

> "In their traverse of the Colorado River and of the rim of the high Plateaus in Utah the members of the Powell survey outlined a large area between the Henry Mountains and the Kaibab Plateau, within which the Kaiparowits Plateau is the dominating feature. Difficulty of access, dry climate, scant vegetation, small amounts of water supplies, and complete absence of human population prevented a study of this region under the conditions then prevailing, and the trappers and prospectors who preceded and followed these early explorers were little interested in making detailed examinations of the sandstones that constitute most of the bedrock.
>
> "In its larger geographic relations the Kaiparowits Plateau region forms part of the Colorado Plateau which comprises 100,000 square miles of strongly tabular relief emphasized by volcanic masses. The outstanding topographic features are terraced plateaus, cliff-bound mesas, monoclinal ridges and straight-sided canyons--all impressive alike for magnitude and ruggedness. Land sculpture is developed on so enormous a scale the features in the landscape unnoticed here would be prominent and picturesque landmarks in other surroundings" (see Figure 21).

Governor Rampton of Utah was recently quoted by the New York Times as saying "the Kaiparowits Plateau is so big you could drop Manhattan Island on it and lose it. Nobody goes there anyway."[90]

A 3,000-MW coal-fired electrical plant and associated coal mines are now to be developed in this region which is presently devoid of modern transportation facilities. The electricity produced in this plant alone would be more than twice the present total annual consumption of electrical energy in Utah. In a region where the total population of the three nearest counties (Kane, Garfield, and Wayne) is about 7,000, the plant and mines would require a new town of about twice that figure for its operation. The capital expenditure would exceed $1 billion, and much of this would be spent in counties where the budget is less than about $100,000.

Slurry Pipelines, Electrical Transmission Lines, and Railroads: The Alternatives

The socioeconomic impact which a development such as Kaiparowits would have on local areas is so large that one might ask why no railroads are being built to connect Kaiparowits coal directly to principal markets. Indeed, why is the energy resource being transmitted by electrical powerlines?

The answer is complex and depends upon a number of institutional and legal constraints as well as on economics. However, it seems pertinent to ask the question in view of the prospect of developments beyond those of the Kaiparowits Project.

The choice for energy transmission should be made on economic grounds using techniques of systems analysis.[91] A detailed cost-benefit analysis is beyond the scope of this Bulletin. Nevertheless, enough information now exists so that some comments can be made which bear upon the answer.

It is not clear that railroads would be favored over transmission lines even if they were shown to be a more economical way to transport the energy resource from the hinterland to the market area. If the coal were brought to California from Utah by rail, it would have to be burned in California to provide electrical energy. Given present technology, many people believe that it is impossible to burn coal in California without violating applicable air quality standards. If true, this could be an example of an institutional and legal constraint set on the transportation mode.

Southern California utilities presently do not burn Utah coal in California because of the air quality standards and other environmental considerations. On the other hand, air quality considerations have not, to date, significantly deterred coal-burning in the State of Utah. If air quality constraints continue to be stronger in California than in Utah, Southern California utilities will seek to burn Utah coal in Utah in order to get the electrical energy into California. They presently have little choice but to build plants in Utah, at least until the air quality constraints in Utah begin to approach those of California.

However, since the air quality standards appropriate to the new powerplants in Utah in principle could be raised in the future by the Utah government, by the Federal government, by Congress, or indirectly even by California State officials, the general problem of choosing among railroads, power transmission lines, and slurry pipelines should be analyzed carefully, and alternatives should be weighed carefully.

It should be noted that the econometric analysis may favor railroads under one boundary condition, but not under another. If one considers the boundaries of the analysis to include the market region and the industrial sector alone, excluding the producing region, then the result may tend to favor electrical transmission lines or slurry pipelines. This could be expected because of the unfavorable topographic factors in the construction of a railroad in the Kaiparowits area, as well as rights of way, union problems, and the financial problems of many railroads.

On the other hand, if the boundary of the analysis is taken to include the producer region and the producer state, then the econometric analysis may very well favor the construction of the necessary railroad connections to existing railroads. This answer results because of the many secondary benefits arising from the availability of railroad traffic to other commodities. Secondary industries can be more easily established, manufactured products can move into the hinterland, new markets for coal can be found outside the State, and markets for other commodities such as agricultural, timber, and animal products can be opened up. Indeed, a north-south railroad link connecting the Kaiparowits region to the Salt Lake City region could conceivably have more desirable long-term benefits to Utah than would the establishment of a new town based upon a single industry, such as is presently contemplated.

A recent study of coal transportation indicated that railroads have many advantages over coal slurry pipelines. This study showed that the construction of a new pipeline is less expensive than the construction of a new railroad, but that if some of the route were to follow existing railroad lines, the initial cost situation would be reversed.[92] Further, the study showed that a railroad offers other substantial advantages in environmental and economic sectors. The study has been used to bolster the case for transporting coal from Lusk, Wyoming, to White Bluff, Arkansas, by existing railroads, instead of by coal slurry pipeline as proposed by a pipeline consortium, Energy Transportation Systems, Inc.[93]

Barriers to New Railroad Links in Southern Utah

There is a great need for a general systems analysis study of an improved rail network in southern Utah. The need is sufficiently strong to justify support for immediate work on parts of the systems analysis study which may be made independently. One such study is an analysis of the physiographic and environmental barriers that must be overcome in order to build the railroad.

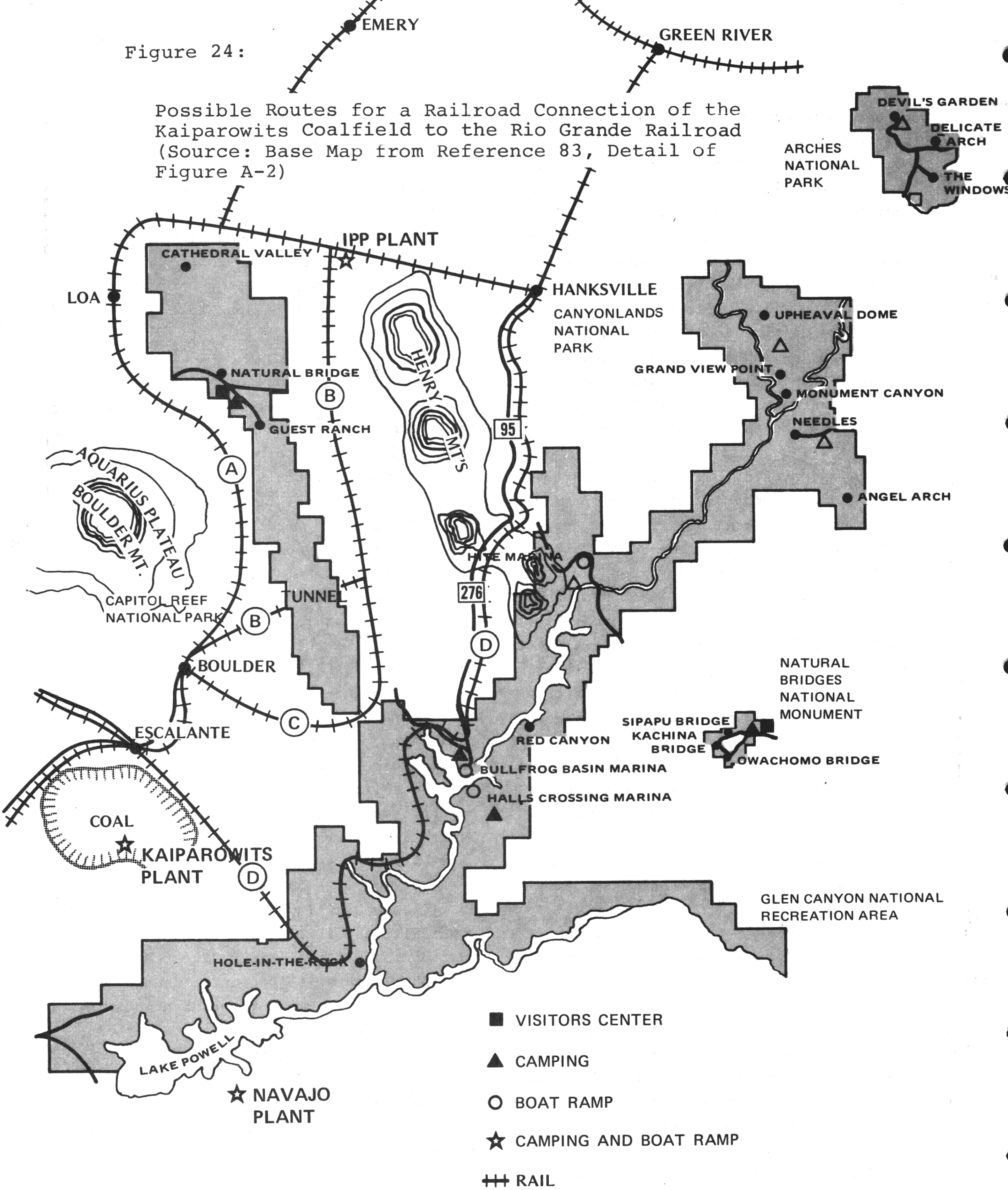
Railroad links between the Kaiparowits region could connect northward with the Rio Grande Railroad, either at Marysvale, Emery, or Green River. A rail link could also be established with the Union Pacific Railroad by building a spur west to connect with Cedar City.

In order for coal to move north by a newly constructed railroad to either the rail terminal at Green River or the proposed rail terminal at Emery, a number of quite difficult topographic or environmental barriers must be overcome. Any possible railroad roadbed would traverse deep and wide canyons, and in some cases would require tunnels. The environmental barriers imposed by National Parks in the area are no less formidable. A rail line could easily be built from Green River to the proposed IPP site at Caineville, passing close to Hanksville. The area is a flat terrain, called the San Rafael Desert. Also, coal from the Kaiparowits coalfield could reach the IPP plant by rail if a line is constructed from the northern end of the Escalante area to Cedar City, Marysvale, Emery, or Green River itself.

Figure 24 illustrates a number of possibilities with their attendant difficulties for railroad lines directed north from the Kaiparowits region. The new railroads could follow the route of Utah Highway 12 to Boulder. From there, a number of barriers are encountered: (1) the steep slopes of Boulder Mountain, (2) the canyons dissecting the base of Boulder Mountain, (3) Capitol Reef National Park, and (4) a great monocline (the Water Pocket fold) which is the main feature of Capitol Reef National Park.

Figure 24:

Possible Routes for a Railroad Connection of the Kaiparowits Coalfield to the Rio Grande Railroad (Source: Base Map from Reference 83, Detail of Figure A-2)



An unpaved road exists between Boulder and Loa (population 384). A railbed could follow this route, marked "A" in Figure 24. This route would require building the roadbed on very steep grades, which would in turn require a railyard for helper engines near Escalante.

Other possible routes are illustrated in Figure 24. There would no doubt be great resistance from environmental organizations to passage of a rail line through a Park by any method, yet it is possible that a railroad line could be constructed to go under Capitol Reef National Park by the simple device of building a tunnel. This is shown by path "B" in Figure 24. Beyond the tunnel, the proposed rail line proceeds north between Capitol Reef National Park and the Henry Mountains along an unpaved road which now exists. Along "B" helper engines would not be needed because this route follows at the base of the Water Pocket fold and is relatively flat, so a large railyard near Escalante would not be required. Another relatively level route, noted as "C," would be from Boulder around the southern tip of Capitol Reef National Park, staying within the narrow confines on Bureau of Land Management land lying between the Park and Glen Canyon National Recreation Area. While "C" could be located entirely on Bureau of Land Management land, it would cross many deep canyons, necessitating the building of numerous bridges. Route "D" in Figure 24 is shown to illustrate the path the railroad might conceivably take if it were allowed to parallel a scenic passageway along the north shore of Lake Powell. The Public Law which established the boundaries of the Glen Canyon National Recreation Area also provided for a study of a possible scenic road along the lake.[94]

A fifth possible railroad route to the north would be through Grass Valley along the east fork of the Sevier River, as shown by "E" in Figure 24. This route would avoid the steep grades of Boulder Mountain, would pass north of Bryce Canyon National Park, and would connect with the rail terminal at Marysvale.

A western route connecting to the Union Pacific Railroad at Cedar City is shown by "F" in Figure 25. The railroad bed would be relatively level, passing between the Vermillion Cliffs and the White Cliffs and along the southern edge of Zion National Park, following the east fork of the Virgin River. It would turn north beyond the Hurricane Cliffs and proceed north to Cedar City parallel to Interstate Highway 15, and then would follow Ash Creek and Cedar Valley.[95]

Slurry Pipelines, Electrical Transmission Corridors, and Railroads: The Tradeoffs

A good case can be made in favor of transporting coal to California by slurry pipelines. Coal is presently transported from Black Mesa, Arizona, to the Mojave Power Plant in Nevada. There is also a plan to transport coal from the Alton coalfield of the Kaiparowits region to the proposed Warner Allen Plant in Nevada. Experience gained in the construction of these pipelines could be used as a guide for the analysis of a proposal, should it arise, for the construction of a slurry pipeline from Kaiparowits to California. There is no doubt that the construction of a railroad would be more expensive, mile for

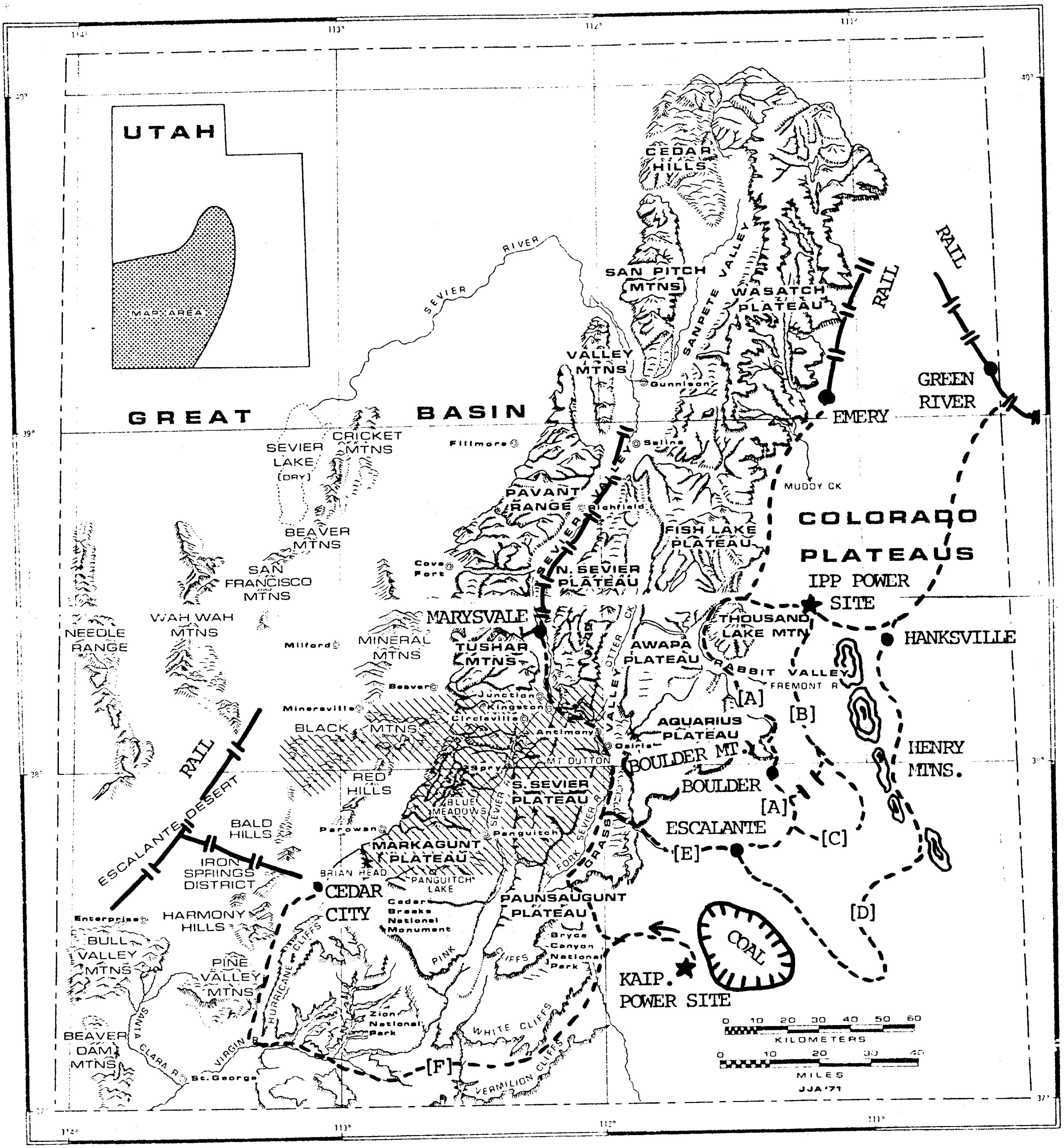


Figure 25: Possible Routes for Railroads Connecting the Kaiparowits Coalfield with the Union Pacific and Rio Grande Railroads (Source: Modified from Reference 95, pages 5,6, Figure 1)

mile, than would the construction of a slurry line or an electrical transmission line in the Kaiparowits region itself.

However, the cost analysis of the construction of a transportation mode between the Kaiparowits region and the Southern California desert has to take into account that a major line, the Union Pacific Railroad, already exists between Salt Lake City, Utah, and Barstow, California. The Santa Fe and the Southern Pacific Railroads have lines connecting Mohave, Inyokern, and Bishop to Barstow (Figure 20). The Santa Fe Railroad connects Needles and Blythe to Barstow.

In order to connect a wide region (from Blythe to Bishop) of the California desert to the Kaiparowits coalfield, a railroad connection only about 120 miles in length would be required between Cedar City and Escalante, Utah. In the case of pipelines, corridors would have to be built for the entire line between the Kaiparowits region and the powerplant site in California. Assuming that the powerplants would be sited in the eastern desert region of Southern California, the length of the corridor would be about 300 miles. Relative expense is an important factor in considering various transportation modes. The choices include: (1) building 120 miles of railroad track in the Kaiparowits region, plus an electrical transmission corridor between the plant site in the southeastern desert of Southern California to the Los Angeles area; (2) laying about 300 miles of pipeline between the Kaiparowits mines and the coal plant site in southeastern California, plus constructing an electrical transmission line corridor for the plant site to the Los Angeles area; or (3) constructing about 450 miles of electrical transmission line between the Kaiparowits Plateau and the Los Angeles area.

More land would be required for the rights-of-way of the long pipeline or transmission line corridors than for the railroad segment needed in the Kaiparowits region. It would seem that the materials (such as steel and copper) required in the construction of the railroad corridor in southern Utah would cost less than would those required for the pipeline and the electrical transmission corridors, stretching as they must across southern Utah, southern Nevada, and then into Southern California.

Although detailed economic analyses remain to be made, rail transportation may turn out to be a competitive way in which to import Utah coal for burning in electrical powerplants within California. The detailed economic study would have to take into account not only the factors mentioned previously, but others as well, such as unit costs of transporting the energy itself, and the associated effects of the various transportation modes upon the economy, employment, and the conservation of metals and water. The relative impacts of construction and transportation upon the environment would have to be considered separately. In a recent study, Rieber and others reported that railroads have more favorable environmental impact than do pipelines.[92] Similar studies, including formal environmental impact statements, would need to be made for alternate transportation modes for Kaiparowits coal.

A model which includes the producer state would have to consider the transportation problems of all of the prospective coal-fired plant sites in Utah. It would have to account for the prospective benefits of railroad transport of other energy resources, such as oil, uranium, and oil shale, which are found in the State. The time frame of the analyses should include forecasts of various energy extraction enterprises over the next century.

In the analyses one would have to consider that the local road transportation system in the Kaiparowits region itself, though primitive at this time, will of necessity be vastly improved because of the construction of the mines. Large, heavy equipment has to be moved on-site and the movement of many workers has to be expedited. This will require the building of wide roads with small grades. The burden of this expense will fall on the first powerplant enterprise in the Kaiparowits region. Once built, this local transportation system will be an advantage to a later enterprise which considers the transport of coal outside the State of Utah.

The planners (such as the Four Corners Commission) in the State of Utah and the intermountain region should consider the advantages of a railroad system which connects southern Utah towns (Escalante, Glen Canyon City, Kanab, and St. George, in one case; Kanab, Escalante, Boulder, and Hanksville in another) with Salt Lake and Utah Counties.

New Towns and Stimulated Growth in Older Towns

One of the large socioeconomic problems of energy extraction in the western states is the construction and operation of an adequate town in a former hinterland to provide for the workers, their families, and the attendant services commensurate with the standard of living presently enjoyed by union members. Gone are the bleak mining towns, with shanties clinging to the sides of the hills. Gone are the days when heavy-construction workers lived many miles from their families for the duration of the job. If good housing is not provided at a new townsite, workers arrange for modern mobile homes and by this action create a new trailer town in a happenstance, random fashion.

Such an unplanned trailer town creates immense problems for the State and county officers. Water and sewage facilities must meet health standards, police and firemen must protect the community in an environment in which social stress is high, courts must provide for criminal and civil cases associated with this social stress, and there must be adequate school facilities to provide an education for a large influx of students. While the cost of constructing an adequate new town is immense, the costs to the State and the county for remedies to problems created by an unplanned town are probably greater.

In the Kaiparowits Draft EIS, a discussion of expected socioeconomic impact is made: "...Statistics from Wyoming suggest a close correlation between crime rate and inadequacy of boom town developments..." and "...Since so-called temporary housing, such as trailer villages, is usually sub-standard as compared with fixed-place residences, some of these workers never enjoy amenities that many Americans with smaller salaries enjoy."[96]

Population forecasts for the increase in population and school enrollment used in the Kaiparowits Draft EIS are given in Table 6.[96] A great effort is required if new schools and new homes in a well-planned town are to be provided for the workers. According to tthe Draft EIS, "Securing the investors and phasing-in

Table 6: Expected New Population in New Towns to Serve Kaiparowits Coal Development

Year	New Town	Garfield County	Page, Arizona
	Distribution of Basic Employees		
1	537	45	179
2	1,203	63	401
3	2,044	86	681
4	2,776	142	925
5	2,860	142	953
6	2,857	143	952
7	2,732	140	912
8	2,572	137	862
9	2,354	131	785
10	2,354	131	785
	Expected Total Population		
1	1,062	117	895
2	2,862	176	2,005
3	5,759	423	3,405
4	8,883	452	4,625
5	10,010	484	4,765
6	10,856	504	4,760
7	10,928	533	4,560
8	10,348	552	4,310
9	9,416	557	3,925
10	9,416	587	3,925
	New Elementary Student Enrollment, Ages 5-14		
1	106	27	203
2	315	40	455
3	691	97	773
4	1,332	104	1,050
5	1,801	111	1,082
6	2,063	116	1,081
7	2,185	123	1,035
8	2,070	127	978
9	1,883	128	891
10	1,803	128	891

Source: Figure 52, Reference 35, pages III-255, 257.

the construction in a time frame that would allow the greatest profit and the greatest convenience for the residents may not occur."[96]

Local road systems in the new town will have to be built to the level commensurate with the needs of the population. Utah may not have the resources for these roads. According to the Kaiparowits Draft EIS, "Gasoline tax revenues are at a low due to the energy crisis, and the state may not be able to finance building the needed roads."[96]

There is a very small housing industry in the two-county area around the proposed Kaiparowits Plant. The number of workers in non-agricultural payrolls for Kane and Garfield Counties is given in Table 7.[97] From this, it can be seen that the local housing and construction industry is quite insufficient for the tremendous job in the construction of the new town.

Most of the finished products and raw materials for the new town, and the new housing starts in the adjacent older towns, will have to be shipped from urban areas where there are adequate production and storage facilities. But how are these materials to be shipped if no arterial transportation corridors exist from the Kaiparowits region to the main urban centers?

One advantage of a railroad link from the coalfields of the Kaiparowits region to the major railroads in Utah is that the materials for a major housing industry could be shipped in from the northern part of Utah or from the Southern California area on the same line on which the coal is shipped out. These same supplies, however, cannot be shipped in on a coal slurry pipeline or an electrical transmission line.

The connection between town growth and major transportation corridors in the assimilation of the western frontier of the United States is understood by every child who watches western movies. Similarly, the growth of the new industrial towns in southern Utah will be interrelated to the transportation system provided to that area. Just as the facilities for an optimum growth of the new town depend on the optimum transportation system, the successful operation of the transportation system depends on the facilities and workers of the new town.

A Recommended Energy Transportation Study

While the chief benefits of such a railroad system would accrue to Utah, there would be some benefits, at least indirectly, to Southern California. IPP, as has been noted, is dependent upon coal being transported to the Caineville area by systems that do not presently exist. The construction of a railroad link between the Kaiparowits Plateau and the Caineville area would solve at least one problem of IPP, and thus would affect the production of power for LADWP. A new railroad might indirectly provide energy to assure the water supply of Southern California. The Department of Water Resources in the Resources Agency of the State of California has the responsibility of providing sufficient energy for the California State Water Project. One alternative energy source for the Department of Water Resources of the Resources Agency would be Kaiparowits coal burned in California. The electric power so generated could provide energy required to pump the water in the State Water Project.

Table 7: Employees on Nonagricultural Payrolls by Major Industry (1974)

Planning District and County	Annual Average	Percent of State Total	Industry			
			Manufacturing	Mining	Construction	Transp. Comm. & Public Utils.
Utah State Total	436,870		69,279	13,289	23,953	26,823
Carbon	5,242	1.20	283	1,087	201	404
Emery	2,082	.48	34	836	420	114
Garfield	1,030	.24	217	19	35	52
Kane	796	.18	64	15	23	9
Wayne	321	.07	14	a	25	a

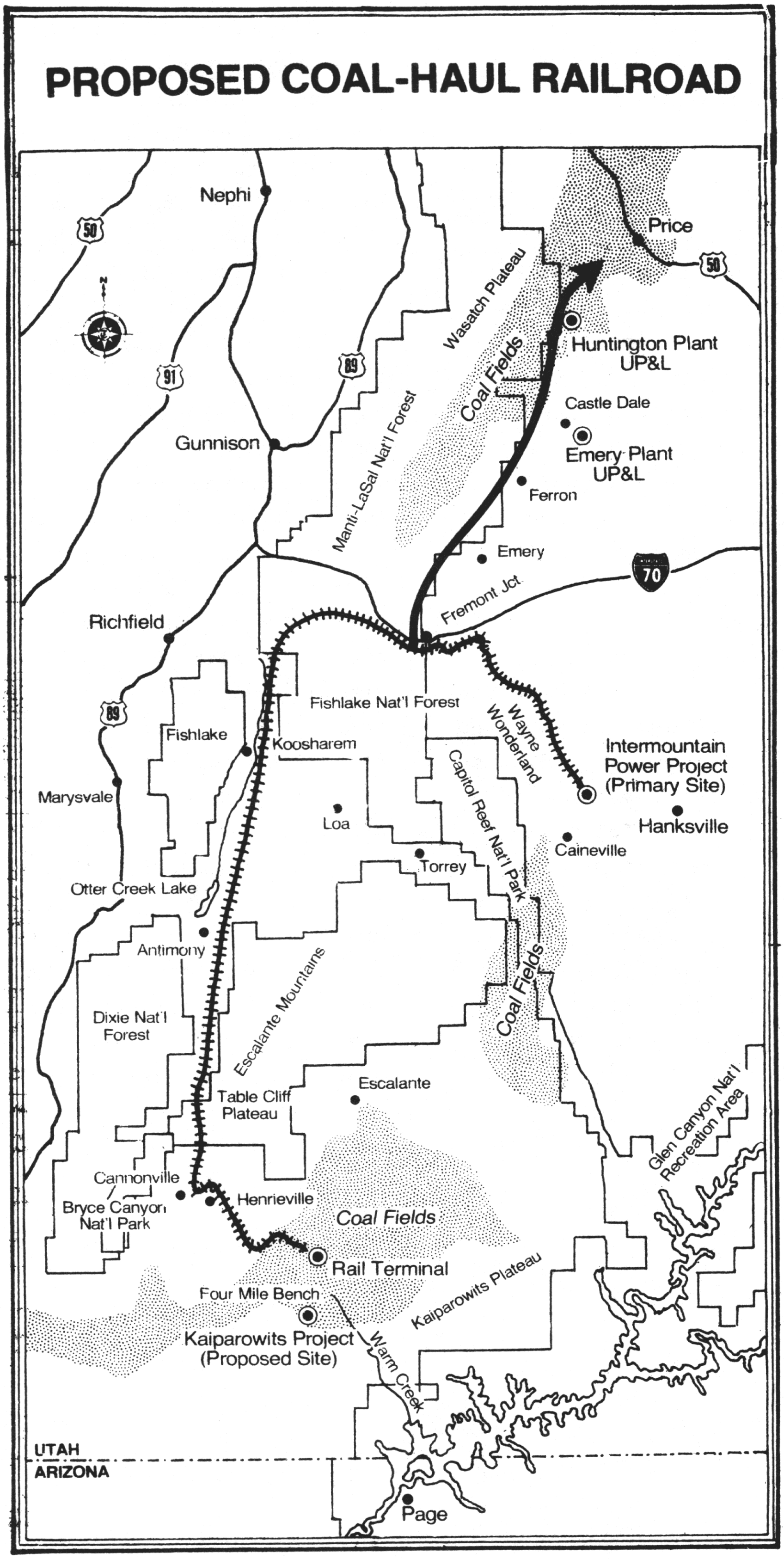
[a] Not shown to avoid disclosure of data for individual firms but included in total

Source: Utah State Department of Employment Security, Reports and Analysis Division, (Salt Lake City, Utah: June 1975).

A railroad system servicing the Kaiparowits coalfield would greatly benefit the nation as a whole. Expansion of the railroads in Utah would facilitate the extraction of all types of energy resources--coal, oil shale, gas, uranium, and oil--from this region for use in the energy-deficient regions of the country. An alternative to the automobile also might be used by recreationists using the region. A north-south railroad system serving the energy resource region in southern Utah would greatly expedite the development of energy resources. A comprehensive transportation study of the energy transport along the Utah-Southern California axis therefore should be encouraged and supported by the States of California and Utah, as well as by Federal agencies.

A study of the possibility of building a railroad from the Kaiparowits Plateau area to the IPP plant has been finished and reported by Morrison-Knudsen Co., Inc.[98] The route of this railroad is similar to that shown by "E" in Figure 25, except that it passes through Salina Canyon, with a spur connecting to the proposed Emery County powerplants. The study was reported to have been jointly financed by IPP, Utah Power and Light Co., and El Paso Natural Gas Co.[98] This railroad could transport coal from the holdings of Utah Power and Light Co. and El Paso Natural Gas Co. The map showing the proposed railroad route is shown in Figure 26 as it appeared in the Salt Lake Tribune.[98]

Figure 26: Proposed Coal Haul Railroad
Source: Reference 98.



Proposed new railroad could carry Kaiparowits coal north to IPP plant. Spur to UP&L plants (solid line) possible.

ACKNOWLEDGMENTS

This is the first of two Lake Powell Research Project Bulletins which were developed from research in the LPRP Kaiparowits Resources Subproject and from discussions in a graduate seminar, "Utah Coal for Southern California Power," organized by Orson L. Anderson and Priscilla C. Grew in the Environmental Science and Engineering Program at the University of California, Los Angeles. The second Bulletin is entitled, "Utah Coal for Southern California Power: Historical Background," by Priscilla Grew (LPRP Bulletin 23).

The author thanks Priscilla Grew and students in the Environmental Science and Engineering class for stimulating discussions and suggestions for revisions in the manuscript. He is grateful to Susan Fry, Gordon Jacoby, Bart Sokolow, Jeni Varady, Eric Walther, Gary Weatherford, and Mike Williams for additional assistance in this study. Myron C. Holburt provided a critical evaluation of the portion of the Bulletin dealing with Colorado River surface flow and the "Law of the River." The author also thanks F. A. McCrackin of Southern California Edison, H. Christie of the Los Angeles Department of Water and Power, B. W. Shackelford of Pacific Gas and Electric, and Jack E. Thomas of San Diego Gas and Electric for checking the data on coal forecasts summarized in Table 1. Don Price of the Water Resources Division of the U.S. Geological Survey provided helpful comments on the section of the Bulletin dealing with ground water. The author, however, accepts full responsibility for the contents and conclusions of the paper. Part of the research for the portions of the paper which treat transportation and ground water was supported by the Los Alamos Scientific Laboratory (Grant No. XP3-12166) during the summer of 1975. The majority of the research was supported by the Research Applied to National Needs Program of the National Science Foundation (Grant No. AEN 72 03470 A03) to the Kaiparowits Resources Subproject of the Lake Powell Research Project. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of the Los Alamos Scientific Laboratory or the National Science Foundation.

FOOTNOTES

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10. Reference 3, page 13.

11. Reference 8, page 16.

12. Reference 3, page 13.

13. Numerous newspaper reports in the period from November to December 1974.

14. Ray, Dixy Lee, The Nation's Energy Future: A Report to Richard M. Nixon, President of the United States, U.S. Atomic Energy Commission Report WASH 1281, U.S. Government Printing Office, p. 48.

    In the report to the President submitted by Dr. Dixy Lee Ray, Chairman of the Atomic Energy Commission, one of the five tasks required to regain and maintain energy self-sufficiency was defined as:

    "Task 3. SUBSTITUTE COAL FOR OIL AND GAS ON A MASSIVE SCALE. This task can be divided into two parts. The first is to switch wherever possible to the direct use of coal where oil and gas are now used, as in boilers in industry and in central power stations...Coal is an enormous domestic resource, and immediate and intensive efforts must be mounted to mine more of it... The second part of the coal-substitution task is the conversion of coal to synthetic fuels."

    From Coal News, No. 4234, October 11, 1974, p. 1:

    "Mr. Ford said he will ask Congress after its election recess for new laws to require use of cleaner coal processes and nuclear fuel in new electric power plants and the quick conversion of existing oil plants. I propose that we together set a target date of 1980 for eliminating oil-fired plants from the nation's base loaded electrical capacity."

    See also Energy Supply and Environmental Coordination Act of 1974, Public Law No. 93-319, Section 2 (June 22, 1974).

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21B. Reference 7, pages 4 and 5.

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77. The second standard is "requisite to protect the public welfare from any known or anticipated adverse effects." 42 USC § 1857 C-4 (b) (2) Public welfare is defined to include "any effects on soil, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility, and climate, damage to and deterioration of property, and hazards to transportation as well as effects on economic values and on personal comfort and well being." 42 USC § 1857 h (h).

78. Class II applies to areas in which deterioration normally accompanying moderate well-controlled growth would be considered insignificant, and Class III applies to those areas in which deterioration up to the national averages would be considered insignificant. 40 C.F.R. § 52.21 (c)(2)(i); and 39 F.R. 42510.

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manuscript received November 25, 1974

first revision received August 20, 1975

final revision received January 16, 1976

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