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Impacts of Energy Development on Utah Water Resources

Barry C. Saunders

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AMERICAN WATER RESOURCES ASSOCIATION

Utah Section

IMPACTS OF ENERGY DEVELOPMENT ON UTAH WATER RESOURCES

Proceedings of

The Third Annual Conference of the Utah Section of the American Water Resources Association

Held at the Rodeway Inn, Salt Lake City, Utah

February 20, 1975

**Sponsored in Cooperation with
Utah Water Research Laboratory at Utah State University and
Utah Division of Water Resources**

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ACKNOWLEDGMENTS

The success of the Third Annual Conference of the Utah Section, American Water Resources Association (AWRA) was dependent upon the efforts of many people. Sincere appreciation is expressed to the directors of the sponsoring agencies for the direct support which they provided--Dr. Jay M. Bagley, Director of the Utah Water Research Laboratory, and Dr. Daniel F. Lawrence, Director of the Utah Division of Water Resources. Gratitude is also expressed to Mr. Arden O. Weiss of the U.S. Water Resources Council for giving a general overview of the water for energy problem in his keynote address, and to Mr. Gordon E. Harmston, Director of the Utah Department of Natural Resources for his luncheon address on the politics of water and energy in Utah.

Gratitude is expressed to those who acted as chairmen of sessions, and to those who presented papers on the program. As indicated by these proceedings, the papers were of a high quality and much thoughtful discussion was stimulated. Special thanks is accorded to those who served on various committees, particularly to Dr. J. Paul Riley, who served as Chairman of the Program Committee and who also assisted in many other ways, including taking much of the initiative in the publishing of these proceedings.

At elections conducted during the annual conference, new section officers were elected for the coming year, with Barry C. Saunders as President, Robert S. Johnson as Vice-President, and Daniel H. Hoggan as Secretary-Treasurer.

Barry C. Saunders, President
Utah Section, American Water
Resources Association, 1975-1976

LIST OF PARTICIPANTS

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Thomas, Dee B.	U.S. Forest Service	Williams, Gerald	Nat'l Weather Service
Weiss, Arden O.	Water Resources Council	Wilson, Dave	U.S.D.A.

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INTRODUCTION

by

Barry C. Saunders*

Choosing a theme for a conference, especially one for a group of diverse disciplines such as the American Water Resources Association encompasses, is always a challenge. You find yourself torn between things you'd really like to talk and hear about, and topics you think will draw attendance. It was most fortunate when somebody came up with the idea of Water for Energy, because to my way of thinking, it met both of these ends.

There is no denying that starting in late 1973, energy has been the catchword, and the energy crisis has been the bandwagon to leap upon. But in Utah, energy is more than potent ad copy. Development of the coal, oil, oil shale, bituminous sands, and geothermal resources within the State can, and perhaps will, turn the state upside down. Whether or not anyone at any level of government will be able to exercise control over energy-related events remains to be seen.

It is no surprise that energy-development in Utah will be governed by the availability of water. What may be more important is the growing evidence that if the laws and policies of the state regarding allocation of water are not changed, energy development will get all the water it needs (through the free market system), and agriculture will be the loser. So the energy crisis will become in effect a "rural life" crisis.

Nearly everybody wants to have economic growth; nearly everybody wants to maintain the environment and aesthetics that have made Utah a pleasant place to live. But can we have both? Water is but one aspect of this question, but in Utah it is a crucial one. The papers that follow discuss technical, economic, social, legal, and political factors associated with water development for energy in Utah. Hopefully, this material will provide new insights and result in more informed and rational decision-making.

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*Vice-President, Utah Section, AWRA.

WATER FOR ENERGY

by

Arden O. Weiss*

Extracts from Appendix to Project Independence Report by Water Resources Tasks Force

Purpose and scope

This report has been prepared in direct response to a request by the Federal Energy Administration (FEA) that the U.S. Water Resources Council (WRC) assist Project Independence to identify and describe problems plus recommend courses of action for accommodating the energy-related water requirements of the nation along with other non-energy related water requirements.

As agreed on April 25, 1974, the WRC has directed its attention in this report to answering the following five questions:

1. To what extent do the energy-related water requirements compete with either existing or anticipated future water uses for other purposes?
2. To what extent can the energy-related water requirements be accommodated along with the other competing uses?
3. What is the magnitude and extent of any water supply shortages, water quality, institutional, and other water supply problems (environmental, capital investment, manpower, inter-basin transfer) that may restrict or prevent selected future condition energy development scenarios from being implemented?
4. What water-related federal actions (policies, programs, investigations, and projects) are required to overcome problems and constraints of the nature described above?
5. What is the hydroelectric power generation capability (existing and potential) and related water requirements to assist in meeting the nation's energy needs?

These questions are addressed in this report with regard to two future condition energy development scenarios provided to WRC by FEA

*U.S. Water Resources Council, Washington, D.C.

on October 17, 1974. Additional scenarios are being developed by FEA but are not addressed in this report.

1. Scenario A -- A "business as usual" future for 1985 which assumes a world price for oil of $11.00 per barrel (at New York) and that no major conservation actions will be employed to induce reductions in the nation's demand for energy. Also, it assumes that no significant additional federal actions will be employed to stimulate domestic production of energy.
2. Scenario B -- An "accelerated" future for 1985 which also assumes a world price for oil of $11.00 per barrel (at New York) and no major conservation actions, but does assume that some significant federal actions will be employed to stimulate the domestic production of energy and thereby, by 1985, provide a significant reduction in the dependency upon foreign sources of energy.

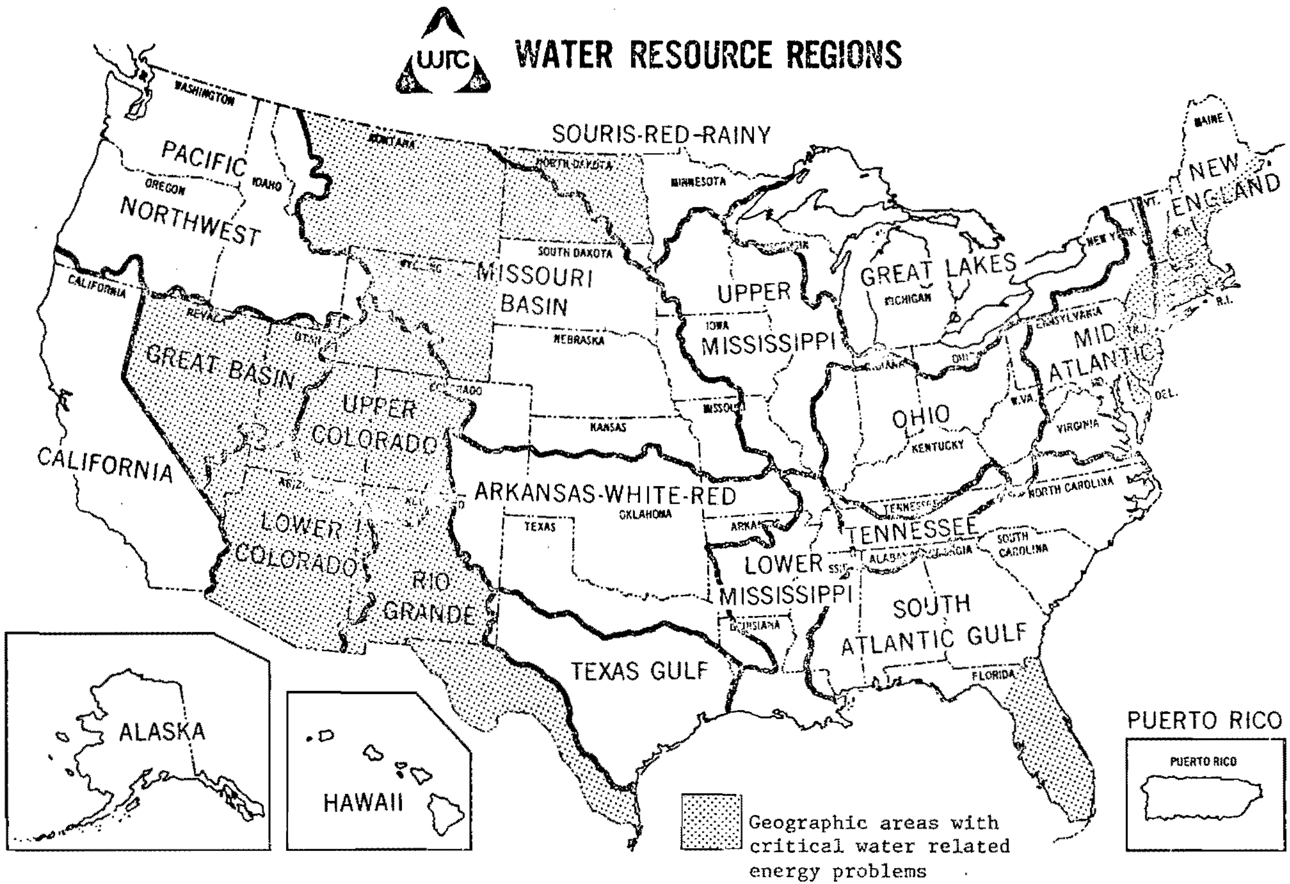
For both scenarios FEA provided withdrawal and consumptive water requirements for each of the Council's 21 Water Resources Regions and for the following categories of energy-related uses:

1. Electric Power Generation
   - Nuclear
   - Fossil Fuel
2. Petroleum Refining
3. Natural Gas -- Extraction and Processing
4. Domestic Crude Oil -- Extraction Including Secondary and Tertiary Recovery
5. Shale Oil -- Extraction, Processing, and Residual management
6. Coal Mining
7. Synthetic Fuels from Coal (Liquefaction and Gasification)

The problems discussed, the conclusions reached, and the federal actions recommended are consonant with the water requirements provided by FEA and reflect the WRC's judgment on problems which the FEA needs to address, policies which should be followed and actions which should be taken.

As agreed by the WRC, the investigations undertaken to prepare this report were nationwide in scope but focused upon each of the WRC's 21 Water Resources Regions shown in Figure 1. Those regions or portions thereof where particularly sever problems or constraints exist are shown in Figure 1 and further explained herein.

Because of their familiarity with the status of water and related land resources in each of the 21 WRC Regions, the federal, regional


WATER RESOURCE REGIONS
wrc
PACIFIC NORTHWEST
SOURIS-RED-RAINY
MISSOURI BASIN
UPPER MISSISSIPPI
GREAT LAKES
NEW ENGLAND
MID ATLANTIC
CALIFORNIA
GREAT BASIN
UPPER COLORADO
LOWER COLORADO
RIO GRANDE
ARKANSAS-WHITE-RED
TEXAS GULF
LOWER MISSISSIPPI
OHIO
TENNESSEE
SOUTH ATLANTIC GULF
ALASKA
HAWAII
PUERTO RICO
WASHINGTON
OREGON
IDAHO
MONTANA
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
IOWA
MICHIGAN
KENTUCKY
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
FLORIDA
CALIFORNIA
MAINE
Geographic areas with critical water related energy problems

and state agencies serving as Regional Sponsors for the 1975 Water Assessment performed a significant part of the analyses leading toward the preparation of this report.

Conclusions and Recommended Federal Actions

The U.S. Water Resources Council, in evaluating the two energy-related water use scenarios provided to the Coucil on October 17, 1974, have presented the following conclusions and recommended Federal actions for your consideration.

I. Water Supplies-Water Requirements

The lack of adequate supplies of water, difficulties in delivering water where and when needed, water rights conflicts, and related environmental and institutional considerations pose major problems and constraints in being able to meet all of the water for energy requirements contained in the two FEA scenarios in the following inland Water Resources Regions or portions thereof:

- o Western portion of Souris-Red-Rainy - Region 09
- o Upper portion of Missouri Basin - Region 10
- o Rio Grande - Region 13
- o Upper Colorado - Region 14
- o Lower Colorado - Region 15
- o Great Basin - Region 16

Multipurpose developments of considerable size and cost may be necessary to provide the amount of water needed for energy development and other purposes.

As shown in Tables 3, and 5 through 7 of this report, little difference exists between the two FEA scenarios. Both scenarios reflect a six-fold increase from 1965 to 1985 in the amount of water consumed for energy development purposes. A large portion of that increase is for electric power generation cooling purposes. The projected increases in water-short regions are even greater.

Further study is required to determine the validity of these projections. Also, it might be more reasonable to assume that power generating facilities would be located in areas where water supplies are less critical.

However, because of the assumption of high utilization of wet cooling towers and consequent fresh water supply constraints plus related water rights and environmental problems, it appears questionable whether the fresh ground and surface water supplies will be adequate to support power generation developments and related cooling needs anticipated by 1985 for the following coastal regions:

- o Northern portion of Mid-Atlantic and Coastal portion of New England - Regiona 01 and 02
- o Florida portion of South Atlantic Gulf - Region 03

To reduce the amount of water consumed, especially fresh water, both before and particularly after 1985, the Council recommends that FEA adopt policies and propose legal regulations and perhaps incentives necessary to encourage electric utilities to use the lowest quality of water available for cooling purposes with heavy emphasis on the use of saline waters.

To further define the nature of these limitations and related problems, the Council recommends that estimates for water provided by FEA be disaggregated to problem area specific locations. Then, and only then, can the true nature of the problems and constraints be analyzed and specific options for providing the necessary water identified.

The Council recommends that the analyses necessary for the development of solutions explicitly take into account land use, institutional, environmental, financial, and other considerations using the Council's multi-objective planning procedures. This effort could be accomplished by the U.S. Water Resources Council with cooperation from its Regional Cooperators. The National Assessment Program (directed by Section 102(a) of PL 89-80 is a logical vehicle for accomplishing the first phase of this investigation.

II. Institutional Problems

Serious institutional problems will accompany many of the activities necessary to meeting the energy-related water requirements identified in the FEA scenarios. In fact, the capability of the existing institutions will be severely taxed, and unless consideration is given to modifying some of the existing institutions, the amount, location, and use of water for energy production may be severely limited in comparison to demands, especially after 1985.

However, attempted abrogation of these institutions in an effort to supply water for energy development will be met with immediate, widespread, and serious objection, almost certainly resulting in extended litigation. Therefore, the Council recommends that to the maximum extent possible, water for energy be provided through existing institutions. Recognizing that States bear a major responsibility for administration of the Nation's water resources, legislatures, if convinced of the need, therefore, can adapt existing systems to encourage and make feasible needed water developments for energy.

The Council recommends that with both Federal and State participation the adequacy of the existing regional and National institutions for management of water and land resources and resolution of conflicts arising from conflicting resource use be evaluated and needed strengthening accomplished. The means of achieving the needed improvements should be specified; and the Water Resources

Council program under Section 102(b) of PL 89-80 should be used to guide and assist in this effort.

The Council recommends that FEA foster the following policies:

- o Modification of existing international treaties with Mexico and Canada should be considered only if they are of benefit to the countries involved.
- o Modifications of existing interstate compacts should be considered only if agreeable to the involved States.
- o Suggested modification of existing water related Federal Acts, Executive Orders, and other Federal agency guidelines required to make water available for energy production should be supported only after giving proper attention to the tradeoffs (with public participation) between economic development, environmental quality, and social well-being of both rural and urban communities.

The Council recommends that before any major shift of water from non-energy to energy uses is pursued (e.g., agriculture to mining) an analysis of both the long and short range beneficial and adverse effects of this shift to the Nation, the region, and the individual users should be made. The results should be expressed in terms of economics, environmental quality, and social well-being, and should be used to guide the extent of the desired shift and the formulation of appropriate institutional arrangements for the implementation.

III. Environmental Problems

Land use, water quality, and other related environmental problems of a serious nature will accompany many of the activities necessary to meeting the water and related land requirements for energy purposes unless stringent controls are maintained. The principal problems are expected to include sediments associated with mining, thermal wastes, acid mine drainage, and both concentration of pollutants and decreased streamflow due to increased consumptive use. Oil, gas, and water removal will increase problems of land subsidence and salt water intrusion in coastal areas.

Many States, Federal agencies, and private entities are alert to, and extremely concerned about the potential adverse environmental impacts of energy development in the critical regions. This may be the most serious restriction to additional development unless adequate safeguards are assured for water, land, and other environmental resources. Meeting statutory requirements for environmental protection of air, water, and land will be expensive. However, the vital necessity and high economic value of energy indicates that costs associated with environmental protection can be met.

The Council recommends that, in order to avoid extensive delay, FEA give high priority to taking actions which will "insure that unquantified environmental values be given appropriate consideration in decision-making along with economic and technical considerations" as stated in the Federal guidelines for preparation of the Environmental Impact Statements pursuant to the National Environmental Policy Act of 1969.

The Council recommends that FEA give high priority consideration to taking actions necessary to insure that the adverse environmental impacts of proposed energy development are reduced to the extent possible and that the associated costs be paid from energy revenues. Only as a last resort should the environmental goals and standards be changed. The extent to which these are proposed for change will require full coordination of the Legislative and Executive branches of the Federal government. Likewise, the results of the ongoing studies of the National Commission on Water Quality should receive full consideration.

IV. Hydropower Use

Conventional hydroelectric facilities produce power without consuming fuel or polluting water or air, are reliable and long-lived, have low operating expenses, are well suited to providing peak and reserve capacity for electrical systems, and are often compatible with meeting other needs, such as recreation, water supply, and flood control. As shown in Table 9, the Nation, by 1993, could increase the current conventional hydropower capacity by approximately 40 percent and thereby save burning about 80 million barrels of oil (or its coal equivalent) annually. Pumped storage hydroelectric facilities can also provide peaking capacity. However, this type of facility has not been considered as fully as conventional hydropower.

The Council recommends that FEA give high priority consideration to utilizing the Nation's hydropower potential in meeting energy requirements.

V. WRC Involvement in Energy

Federal water projects are seldom initiated without strong State support and almost never undertaken in opposition to State desires. Therefore, the Council recommends that FEA work closely with the Council and its member agencies and State water agencies in developing Federal energy policies and actions which affect use of the Nation's fresh and saline waters.

VI. Budgetary Considerations

The Federal water-related capital investments required to meet the water requirements for energy are expected to be fairly substantial even though the ratio of water investments to total investments will be low. Therefore, the Council recommends that FEA emphasize that adequate attention be given to assuring that the water component of the Federal energy budget be given equal priority with the energy production components.

VII. Previously Recommended Activities

Early funding of certain projects, programs, and investigations which can in the near future produce energy, provide water for energy purposes, or lead toward elimination of institutional and other impediments to water availability will assist in achieving energy self-sufficiency.

STUDIES UNDERWAY OR PROPOSED PERTINENT TO WATER FOR ENERGY

Name	Region	Purpose	Implementing Agency
Studies Underway			
Lower Yampa	Upper Colorado	Water for oil shale	Bureau of Reclamation
Yellow Jacket	Upper Colorado	Water for oil shale production	Bureau of Reclamation

PROJECTS AUTHORIZED WHICH WOULD PROVIDE WATER FOR ENERGY

Name	Region	Water Supply	Implementing Agency
Dallas Creek Project	Upper Colorado	57,000 Af/Yr. for energy	Bureau of Reclamation
West Divide Project	Upper Colorado	248,000 Af/Yr. M&I and oil-shale water	Bureau of Reclamation
Western En ergy Expansion Study	All Western Regions	Examine potential for expansion of existing hydro plants	Bureau of Reclamation

Name	Region	Additional Capacity	Agency
Studies Underway			
Dominquez Reservoir Project	Upper Colorado	1,250,000kW peaking	Bureau of Reclamation
Upper Colorado Storage Power Peaking Project	Upper Colorado	Potential 7,500,000kW hydro peaking Capacity	Bureau of Reclamation

The Council recommends that priority activities include:

a. Accelerated completion of projects now under construction or ready for construction which furnish energy with a minimum of water quality or other environmental degradation;

b. Accelerated completion of those projects now under construction or ready for construction which provide large or essential water supplies specifically identified for energy-related water use; and

c. Completion of ongoing, and initiation of new water management studies aimed at defining how to resolve the most serious and widespread impediments to provision of needed water supplies for energy uses.

Prior to the availability of specific energy-related water requirements, the U.S. Water Resources Council developed a "Water-For-Energy Self-Sufficiency" report for transmittal to the Council's Chairman. This report recommended a set of projects, programs, and investigations for early funding, irrespective of which scenario is implemented. Projects, programs or investigations included in that recommendation met the following criteria:

a. There had to be a demonstrated need for the project, program, or investigation and over 50 percent of the need had to be in direct support of energy development activities;

b. The project, program, or investigation had to be in some form whereby it was being considered for initial or continued Federal funding in FY 1976;

c. The project, program, or investigation had to be free from major impediments which would prevent it from being implemented at an early data; and

d. There had to be both a significant Federal role in the project or investigation and considerable State and Federal support for its implementation.

Assumptions-FEA Scenarios

The energy scenarios provided for analysis by FEA and briefly described in Chapter I represent alternative levels of National energy development. Each scenario also comprises a different mix of the types of energy development which might be considered.

The scerarios were synthesized through use of a computerized mathematical model using information provided by nine fuel group task forces which were each assigned responsibility for one or more energy areas (i.e., oil, gas, coal, nuclear power, hydropower, oil shale, synthetic fuels, solar, geothermal). The Task Forces estimated the unit requirements for water (withdrawal and consumption) based upon the water related set of assumptions described in the following material plus other non-water related assumptions not described herein. Each of the processes for providing fuel or energy require water in different amounts and for different purposes. Numerous assumptions discussed in the following material and the unit requirements summarized in Tables 1 and 2 were necessary in computing total water requirements.

Based upon these assumptions, unit requirements and othe r related development costs and resource constraints (capital investment, manpower, water, facilities, and transportation) the mathematical model solved for the national level and regional allocations of water requirements for each of the following types of fuels included in the model.

1. Electric power generation
   - o Nuclear
   - o Fossil fuels
2. Petroleum refining
3. Natural Gas-extraction and processing
4. Domestic crude oil-Extraction, inlcuding secondary and tertiary recovery
5. Shale Oil-Extraction, processing, and residual management
6. Coal mining
7. Synthetic fuels from coal (liquefaction and gasification)

<u>Synthetic oil and gas production</u>

Since there are no modern-design coal gasification plants of commercial scale in the United States, estimates of water demand were based upon research operations, foreign experience, and design data for projected plants. The plant designs for the eastern and western states are distinguished through the characteristic of the input coal and the amount of water withdrawn and consumed. Because of the lower heat value of western coals, the amount of feed varies by a factor of 1.48 from west to east. Also, the quantity of cooling water used in the western plants was assumed to be approximately 50 percent less than eastern plant requirements. This differential is due to an assumed greater use of air cooling (rather than evaporative cooling) and the redovery of water from the feed coal(40 percent moisture for western coal).

Electric power generation-Nuclear

The amount of water withdrawn depends upon the maximum temperature rise acceptable in the discharge cooling water and the degree to which recycling takes place. For a standard plant of 1000 megawatts electrical there was assumed to be a 15°F temperature rise across the condenser, therby requiring approximately 58 gallons per kilowatt hour of flow through the condenser.

The nuclear plant consumptive use factor of 0.8 gal/kwh was derived after assuming an 80 percent load factor and a 32 percent thermal efficienc

The withdrawal and consumption coefficients over time were estimate by using the state level data on annual requirements and percentage consumption provided by the Nuclear Task Force. The mix of types of cooling method and type of plant provide an individual state-aggregated projection of state water withdrawal and percentage consumed.

Fossil fuels

Included in this category are oil-, coal- and gas-fired steam turbine and gas turbine plants and combined cycle gas and steam turbine power plants.

The water use for the combined cycle steam and gas turbine units depends upon the type of cooling systems utilized. The scenarios assumed evaporative cooling towers. For 1985, FEA assumed that a "standard" plant had a capacity of 900 Megawatts electrical and operated with a thermal efficiency of 42 to 44 percent. Also, a 16°F rise in temperature through the condenser was assumed.

Oil shale

The most significant assumption made about the production of oil from shale is that all water withdrawn for use is consumed either in the extraction process or by using it to compact and stabilize the spent shale. Table 2 shows the oil shale production unit water requirements for a 100,000 barrel per day surface mine plant which was assumed in both scenarios.

Table 1. Unit water requirements for producing energy.

Energy Source	Standard Unit	Consumption For Water	Water Needed Gal/10^6BTU	Water Uses of Considered
Western coal mining	ton	6-14.7 gal/ton	0.25-0.61	Dust Control Coal Washing
Eastern surface mining	ton	15.8-18.0 gal/ton	0.66-0.75	Dust Control Coal Washing
Oil Shale	barrel	145.4 gal/bbl	30.1	See table 2
Coal gasification	MSCF[a]	72-158 gal/MSCF	72-158	Process use Cooking Use
Coal liquefaction	barrel	175-1,134 gal/bbl	31-200	Process use Cooking use
Nuclear	kilowatt hour	0.80 gal/Kwh	234.46	Cooling, uranium mining
Oil and gas production	barrel	17.3 gal.	3.05	Well drilling, secondary and tertiary recovery
Refineries	barrel	43 gal/bbl	7.58	Process Water; Cooling Water
Fossil fuel power plants	Kwh	0.41 gal/Kwh	120.16	Cooling Water
Gas processing plants	MSCF	1.67 gal/MSCF	1.67	Cooling Water

[a]Million standard cubic feet

Table 2. Oil shale production water requirements for a 100,000 barrel per day surface mine plant.

Production Processes	Gallons per minute	Acre-Feet per year
Processed Shale Disposal	4,500	7,245
Shale Oil Upgrading	2,300	3,703
Power Requirements	1,100	1,771
Retorting	800	1,288
Mining and Crushing	500	886
Revegetation	220	354
Sanitary Use	30	48
Associated Urban	900	1,449
Totals	10,400	16,744

Other fuels

Oil refineries were assumed to have a standard capacity of 200,000 barrels per day. "Standard" gas processing plants were assumed to have a capacity of 150 million standard cubic feet per day.

Western coal was assumed to be unwashed. All eastern coal was assumed to be washed.

It was assumed that 17.3 gallons of water were required to extract 1 barrel of petroleum. This number was derived from data on the water requirements for secondary and tertiary extraction processes and the amount of water required to drill an average well 10,000 feet deep.

Water for Energy Problems

Primary energy sources include fossil fuels, nuclear fuels, and water power. Presently, fossil fuels contribute about 92 percent of the nation's energy, nuclear fuels about 4 percent, and water power 4 percent. Both nuclear and water power are generally used to generate electricity. Fossil fuels are used for a variety of purposes.

In addition to water's energy related role in hydroelectric generation, it is necessary for the mining, transportation, conversion, and use of various fuels.

In planning for the development and use of water supplies for energy-related purposes, numerous problems will be encountered which must be given full consideration. The problems expected to be encountered are included in the following categories for discussion purposes:

- Water Supply Problems
- Institutional Problems
- Environmental Problems (including water quality)
- Financial Problems

The exact problems which will arise in the future cannot be fully identified until specific proposals for water use are put forward. However, the general characteristics of some of the more likely problems are described in the following.

Options for problem resolution

Numerous methods exist for increasing water supply availability for energy-related purposes. In humid regions of the country, three traditional methods which are generally capable of ensuring adequate supplies are construction of additional surface water reservoirs, drilling of additional wells, and increased use of brackish and other lower quality waters.

In arid and semi-arid regions, most of the available surface and groundwater may already be utilized or legally committed for other current or future purposes. Therefore, other methods of increasing water supplies in addition to the traditional ones must be employed in the arid regions. Among the methods being considered are concerted efforts in conservation, inter-basin diversions, weather modification, and reallocation of water rights from existing uses.

Notwithstanding the above generalizations, it must be pointed out that numerous specific problems exist within regions of the same climatic distinction or even within a single region. Therefore, solutions often will have to be tailored around specific problem areas within each region.

It should be noted that, in most areas where water is not abundant, needs for water purposes other than energy development may also be presently unfulfilled. Efficiency in the structural works necessary to store, transport or otherwise make water available may, and usually will, require multipurpose development. Such developments are frequently complex multistructure projects extending over or influencing large areas.

For policy and program development purposes, this report categorizes the methods for increasing water supplies into the following three major options:

I. Conservation Option-Methods which will cause the water being used for both energy and non-energy purposes to be used more efficiently and therefore, meet energy-related requirements more fully.

II. Supply Enhancement Option-Methods which will increase the water supplies available for energy without significantly detracting from existing and future water use for other purposes.

III. Reallocation Option-Legal and financial methods which will change the future allocation of the existing and presently committed water supplies among the users competing for a limited supply.

Conservation	Supply Enhancement	Reallocation
o Use of Energy Efficiencies	o Surface Reservoirs	o Purchase and Reallocation
o Use of Water Efficiencies	o Wells	
o System Management Efficiencies	o Desalination	
o Reclaimed Water	o Weather Modification and Snowpack Management	
o Phreatophyte Removal	o Interbasin Transfer	

Regional perspective

To assist the reader in focusing upon the nation's critical energy-related problems, the regions with the most critical energy-related water supply, institutional, environmental, and capital investment/repayment problems are as follows:

First, the model, in solving for 1985 conditions, did not seem to be constrained sufficiently to take into account that 10 years or more are required to bring major new energy development facilities on-line. Therefore, the 1985 scenarios do not appear to properly reflect energy use and supporting fuel supply facilities which are currently known of within the regions, and are either in the early stages of planning, or further advanced. This is especially true with respect to the mix of nuclear versus fossil fuel fired facilities.

As a result, it appears necessary to further investigate the numbers resulting from the 1985 scenarios and the water and energy related assumptions and constraints used in the model prior to making significant irreversible resource and capital investment decisions based upon the current modeling results.

Second, the model, while perhaps not being properly constrained for 1985, is of value in solving for year 2000 conditions and therby pointing out a general direction that the nation should head with respect to the nation's energy demands. In this time frame there is considerable flexibility and sufficient time to change the direction of current plans.

Upper Colorado -- Region 14

The surface water supply of the Upper Colorado River Basin is measured or computed at Lee's Ferry, the boundary point between the Upper and Lower Colorado Basins. Available records show an average annual natural flow of 15.0 million acre-feet for the 1960-1973 period from the 113,500 square mile drainage area above Lee's Ferry, Arizona. The flow has ranged from a low of 5.6 million acre-feet in 1934 to a high of 24.0 million acre-feet in 1917. In addition to the extreme variability from year to year, multi-year periods of persistent below or above average occurred. Use of water within the Upper Basin is highly dependent upon storage facilities and the laws and compacts that govern the Colorado River. Only a portion of the 15.0 million acre-feet is available for use in the Upper Colorado River Basin. Storage facilities are needed for most projects and functional water uses throughout the basin for annual

WESTERN REGIONS

- Western portion of Souris-Red-Rainy -- Region 09
- Upper portion of Missouri Basin --Region 10
- Rio Grande -- Region 13
- Upper Colorado -- Region 14
- Lower Colorado -- Region 15
- Great Basin -- Region 16

EASTERN REGIONS

- Northern portion of Mid-Atlantic and Coastal portion of New England -- Regions 01 and 02
- Florida portion of South Atlantic Gulf -- Region 03

The remaining regions, while not rated as critical regions, will have some geographical specific problems that, in general, can be handled without special federal actions.

Critical regions - synopsis

The most severe water supply problem in the Eastern critical regions is associated with fresh water consumptive use for cooling of electric power generation facilities, related thermal and refinery pollution problems, and the incompatibility of development with the desire for return to or maintenance of a natural environment held by a large vocal segment of the population. The solution to this problem lies in giving proper attention to environmental and social concerns as well as utilizing wherever possible, saline off-shore waters for cooling purposes.

The most severe water supply problem in the Western regions is associated with fresh water consumptive use and salinity problems for mining and processing of the oil shales and coal reserves currently planned to be exploited. The most significant constraint related to this problem is of an institutional nature (water rights) and must be resolved before significant increases in consumptive use for energy development can be accommodated. The solution ot this problem is very complex and will require major state/federal actions which are mutually acceptable to both parties.

In evaluating the FEA scenarios and the analytical model used to solve for both the mix of fuels used to meet the nation's energy demands and the regional allocations thereof, the following observations were made.

Categories of Use 1,000's Acre Feet	Upper Colorado Region 1965 From 1968 Assessment	Upper Colorado Region 1985 Scenario A	Upper Colorado Region 1985 Scenario B	Upper Colorado Region 1985 From 1968 Assessment	Great Basin Region 1965 From 1968 Assessment	Great Basin Region 1985 Scenario A	Great Basin Region 1985 Scenario B	Great Basin Region 1985 From 1968 Assessment
Non-Energy Related Use	2,870	4,700		4,700	2,860	3,740		3,740
Energy Related Use	31	462	530	70	6	83	94	51
-Electric Power	20			20	2			45
Nuclear		9.5	13.2			-	-	
Fossil Fuels		293.8	241.0			62.1	66.7	
-Petroleum Refining		110.6	78.8			19.3	27.0	
-Natural Gas		0.4	0.94			0.9	0.36	
-Domestic Crude Oil		5.1	5.1			0.2	0.25	
-Shale Oil	11	42.0	168.0		4	-	-	35
-Coal Mining		0.3	0.36			0.1	0.05	
-Synthetic Fuels		-	23.0			-	-	

regulation and short-term carryover. The major main stem Upper Basin reservoirs, Flaming Gorge, Lake Powell, and the Curecanti system, also provide for long-term carryover storage to deliver water to the Lower Basin under terms of the Colorado River Compact of 1922 and to allow continuous use above Lee's Ferry. The reliable supply must be further reduced to carry through an extended period of below average runoff with reasonable shortages.

Problems, constraints, and recommended federal actions

Use of the water in the Colorado River system is governed by the Colorado River Compact signed in 1922, the Mexican Water Treaty signed in 1944, the Upper Colorado River Basin Compact signed in 1948, and other federal and state laws. The Colorado River Compact divides the Colorado River water between the upper and lower basin with 7, 500, 000 acre feet per year to each. It requires the upper basin states to provide a flow of 75 million acre feet for any ten consecutive years at Lee's Ferry. The Mexican Water Treaty guarantees the delivery of 1, 500, 000 acre feet of Colorado River water to Mexico. The Upper Colorado River Basin provides 50, 000 acre feet of water per year to Arizona. Of the remainder, Colorado is to get 51. 75 percent, New Mexico 11. 25 percent, Utah 23 percent and Wyoming 14 percent.

Many attempts have been made to determine the amount of water available to the Upper Basin States for their annual consumptive use. Differing amounts have resulted from varying interpretations of Compact provisions and methods by which analyses were made. Two of the most familiar are:

1. Department of the Interior. Analyses have been used to support actions and proposed plans of development such as the Central Arizona Project. It estimated that at least 5. 8 million acre-feet would be available for consumptive use annually in the Upper Basin. Pertinent bases and hypotheses used to derive the 5. 8 million acre-ffet figure include releases to the Lower Basin of 8. 25 million acre-feet for power generation and other purposes, operation of the storage project.

Utilization of groundwater as an interim or conjunctive supply is an alternative for partial fulfilment of the basin water needs. Water quality and streamflow depletion effects, however, are constraints that must be considered in relatively large scale withdrawals. The potential for use of groundwater is significant throughout Upper Colorado River Basin. Considerable quantities of groundwater could be pumped; however, pumping more than the annual recharge rate would represent mining, or depletion of the groundwater in storage in the basin.

In addition to energy uses, there are many additional water uses which must be considered and planned for. These include municipal, consisting mostly of exports from the basin and other industrial, agricultural, and environmental water needs. The amount of water needed for future agricultural uses consists primarily of irrigation, however, this could significantly especially in the States of Colorado and Utah through reallocation or through the economics of the marketplace whereby agricultural water could be purchased and reassigned to other purposes through the normal state water rights processes. Future water needs for environmental purposes such as fish and wildlife, recreation, water quality, and esthetics, although more difficult to assess and assign, are nevertheless important. As much as an additional 150,000 acre-feet attributal to these pruposes could be required for consumptive uses alone, with another uncertain amount necessary for minimum instream flows in critical stream reaches.

Water supply and depletions are key problems to each of the states of the Upper Colorado Basin since the percentage allotments and stages of development in each State vary widely. The Upper Colorado River Basin surface water supply is overappropriated in some states. This is especially true in Colorado and Utah where water rights exceed not only the present water use but also the long-term potential water supply. Consequently, there is no meaningful way of reconciling individual appropriations or group appropriations with present water use figures. Where the supply is already over-appropriated, additional water users must obtain water rights out of these existing established rights in most cases.

The quality of water delivered to the lower basin is a major problem now under study by the Bureau of Reclamation. A massive attack on this problem was authorized on June 24, 1974, in the "Colorado River Basin Salinity Control Act" Public Law 93-320, which authorized a desalting complex and related works downstream from Imperial Dam, and also authorized the initial stage of the Colorado River Basin salinity control program upstream from Imperial Dam, including units in the Upper Colorado River Basin.

It must be recognized that the determination of the 5.8 million acre-feet as a possible limit of Upper Basin use is only valid for the particular set of assumptions mentioned above. Other combinations of assumptions, particularly those associated with downstream deliveries, period of years used for water supply and system operation, future condition of reservoirs due to sediment accumulation the distribution of uses (i.e., irrigation, industrial or export), and the future year to which uses are projected would alter the total water available. Reduction of releases to the Lower Basin below 8.25 million acre-feet would increase the level of available water for use in the Upper Basin by far the greatest amount. Other hypotheses could either increase or decrease the available supply by a smaller but substantial annual amount.

2. Upper Colorado River Commission. An engineering consultant, Tipton and Kalmback, Inc., Denver, Colorado, prepared a study entitled, "Water Supplies of the Colorado River, 1965," for the Upper Colorado River Commission which determined that 6.3 million acre-feet would be available for consumptive use if 7.5 million acre-feet only were delivered to the Lower Basin and no shortages were caused-a substantial difference from the minimum assured supply derived in the Department's study described above. If this variation in assumptions is taken into account, the results of the two studies are essentially the same. Many changes in development plans have occurred since these studies were made and will continue to occur as priorities shift and technological advances evolve.

The present (1974) level of depletions from the Upper Colorado River system above Lee Ferry total 3,187,000 acre-feet. Main stem reservoir evaporation was computed to be 520,000 acre-feet, so the present utilization totals 3,707,000 acre-feet. Depletions include all of the average annual man-caused on-site uses within the Upper Basin for agriculture, municipal, industrial, fish and wildlife, recreation, and net export of water above Lee's Ferry together with evaporations from reservoirs associated with these functions. These depletions do not include on-site use of surface and subsurface water on public lands which is used through management of natural resources programs. Using 5,800,000 acre-feet of water as a conservative estimate of the water available and 3,700,000 acre-feet as the current use, approximately 2,100 acre-feet are not being utilized in the basin at present.

In conclusion, sufficient water in the Upper Basin to meet energy developments and other anticipated needs will not be available unless certain state and federal actions are taken soon. These actions include strong state leadership in the resolution of water rights and water allocation actions and the attainment of efficiency in water use. Additional storage facilities will be required. Groundwater can be utilized as an interim supply prior to development of surface storage and subsequently as a conjunctive supply. The adoption of air cooling for thermal power plants and the shift of water use from agriculture to industry will also be necessary to some extent. This picture is the situation as it is seen today and the rapidly changing energy situation can produce a much different picture in a short time. Therefore, an in-depth appraisal must be continued with close cooperation among state and federal interests and industry. FEA should work closely with the Department of the Interior and the states in solving problems relating to water supply, water quality, environmental constraints, and related matters in the development of energy resources in the Upper Colorado.

Great Basin -- Region 16

This region of approximately 136,700 square miles includes most of Nevada, about half of Utah, and small portions of Idaho and Wyoming. The Great Basin is composed of hydrologically close basins. Drainage of these basins terminates in lakes or sinks. These lakes tend to evaporate completely or become more saline with time as salts remain as the water evaporates. The Great Basin is the most arid of the 21 water resource regions with an average annual precipitation of about 11 inches.

The total estimated surface water supply is about 6 million acre feet annually, although only about 1.6 million acre feet of the estimated average annual runoff is measured at the maximum flow gaging stations on the principal rivers in the region. There is a large volume of groundwater in numerous valley basins throughout the region, which is a potential source of water supply for energy and other needs. Most of this groundwater supply is available on a one time use basis only, and these supplies may require treatment, depending on the use.

Problems, constraints, and recommended federal actions.

There are a number of water-related problems throughout the Great Basin because of its relative scarcity and the expense of water development. In the eastern portion of the basin, water for the fast growing Wasatch Front is a main problem, which is partly being solved by construction of the Bonneville Unit of the Central Utah Project, which will import 136,600 acre feet annually from the Colorado River Basin to the Great Basin.

In the western portion of the basin, additional water is needed for the fast growing Reno and nearby areas, where there are complicated conflicts or difficult regulation and management problems involving the Carson-Truckee, Humboldt, and Walker Lake basins.

Energy needs can be met largely by expansion of existing or new facilities of established energy-oriented utilities, located in or near the Basin. Without additional water, future needs will likely have to be met largely by energy imports.

WATER FOR FUTURE ENERGY DEVELOPMENT IN UTAH

by

Daniel F. Lawrence*

At the present time, water users in Utah are diverting about 6 million acre-feet annually for all purposes.

Ninety-percent of the present use is for irrigation. We are diverting about 5 million acre-feet of water to irrigate roughly 1.5 million acres of land. We are using only 500,000 acre-feet of water for M & I purposes--only a tithing of the total water use. Furthermore, in 1975, only 19,000 acre-feet of water is being diverted for the production of electrical energy from thermal electric plants.

The present energy crisis, and the fact that the apparent short-term solution to the problem of meeting energy needs is the use of coal for thermal plants, has attracted a great deal of attention from the public--and nearly everyone is now an "expert" on the water problems of Utah. As a matter of fact, however, the situation is quite complex in that there is no one "pat" answer to the question--Do we have enough water to meet these potential demands? (Most of the coal is in the Colorado River Basin; and, therefore our real competition for energy and agriculture will probably be for Colorado River water.)

Under the 1922 Compact, the River was theoretically divided at Lee Ferry, with 7.5 million acre-feet granted to each of the two divisions (Upper and Lower) of the Colorado River Basin.

The 1948 Compact allocated the Upper division share on a percentage basis. Utah is allocated 23 percent of whatever amount of water is available to the four states--New Mexico, Colorado, Wyoming, and Utah, above Lee Ferry. Based on the long-term average of water in the River system, and based on some other assumptions with respect

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to international treaties and Compact interpretations, the Division of Water Resources has estimated that Utah's depletion entitlement would average 1.4 million acre-feet annually. Present depletion is approximately half of the entitlement and, therefore, it is obvious that about 700,000 acre-feet annually of our water is flowing past Lee Ferry, and is being used by California. (Incidentally, California has constructed the State Water Project, to move water from Sacramento to Los Angeles to meet the Los Angeles needs when Arizona and the Upper Basin ultimately use their entitlements and California's use of Colorado River water is brought down to Compact entitlements.)

Potential use of water for developing energy from coal and oil shales has been estimated in excess of 200,000 acre-feet annually. The probability of these uses becoming realities is hard to evaluate. Virtually all of the 700,000 acre-feet of unused water in the Colorado has been "committed" by approved water rights allocations and by proposed projects, primarily for agriculture. The political feasibility of constructing some of these projects in light of all of the harassment from the so-called "public," on environmental issues, remains in doubt. By the same token groups who were not in favor of constructing dams for agriculture will also oppose development for energy--perhaps more vigorously.

The fact of the matter is that the population of Utah will increase, regardless of whatever policies to the contrary might be adopted; and the demand for water to be used consumptively will require that Utah utilize her full entitlement to the Colorado River, rather than let that water flow down the River.

There is opportunity, to a limited degree, to re-evaluate proposed projects being financed with public funds; and this is being done by the Federal govenment and by the State.

A fact not generally discussed is the property rights aspect of water in Utah. Beginning 125 years ago, water rights have been acquired and utilized throughout the State, and these are recognized as property values and cannot be confiscated or "taken" from those who have the rights. Therefore, it must be recognized that those in the Colorado River Basin who own water rights may choose to sell those rights for energy development. If the use of such purchased water does not interfere with a more important use, no Federal or State agent or officer can prevent the sale.

The foregoing is intended as a preliminary to discussions on October 22; and, in summary, the following points are made:

1. Some quantity of water will be available for direct allocation by the State Engineer to future uses of every kind.

2. The Federal Bureau of Reclamation and the State Board of Water Resources each have water rights based on specific potential projects; and these projects could be modified or even abandoned and the water reallocated for different purposes.

3. The free market system can operate within some constraints to make water available for new uses--probably transfer from agriculture to industry. Contrary to popular belief, this is a desirable transfer from the standpoint of owners of these water rights. Water can bring a much greater price for industrial uses than for agricultural.

4. In spite of popular clamor, water is probably not the limiting factor in determining whether Utah will develop her energy resources. Political considerations regarding the use of public lands, and other environmental impacts, will have greater effect in the decision-making process.

5. Water has already been allocated for several major industrial energy projects.

SALINITY IMPACTS OF ENERGY DEVELOPMENT IN UTAH

by

Michael B. Bessler*

Introduction

The salinity impacts of energy development in Utah cannot be addressed adequately without first gaining a perspective of the total salinity problem in the Colorado River Basin. Thus, recent salinity control legislation and control programs are discussed with emphasis on the specific features in Utah. The cumulative salinity impacts of select energy development sites in Utah are quantified for comparative purposes. Finally, the use of degraded quality water for energy development is advocated in order to minimize impacts on salinity and remaining fresh water supplies.

Salinity Control Legislation

The recent passage of the Colorado River Basin Salinity Control Act of 1974 (Public Law 93-320) sets in motion a bold new step in water quality improvement. The act provides for the construction, operation, and maintenance of certain works in the Colorado River Basin to control the salinity of water delivered to users in the United States and Mexico. The act is essentially an outgrowth stemming from a recent agreement with Mexico in an effort to find a permanent, definitive, and just solution to the international salinity problem with Mexico and the Environmental Protection Agency (EPA) Enforcement Conference

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proceedings of 1972 [4] dealing with the salinity issue throughout the basin.

Under the agreement with Mexico, Colorado River water delivered to Mexico shall have an annual average salinity of no more than 115 mg/l (plus or minus 30 mg/l) over the average annual salinity of waters arriving at Imperial Dam (near Yuma, Arizona). This requirement became effective with the authorization of Title I of the act to construct a large-scale, 100 million gallon per day desalting complex and other associated works necessary to achieve the stated differential in salinity.

Title II of Public Law 93-320 provides for the construction of four salinity control units as the initial stage of the Colorado River Basin Salinity Control Project located upstream from Imperial Dam. The law also provides for expediting the completion of planning reports on three point sources, four irrigation sources, and five diffuse sources of salinity as outlined in the Colorado River Water Quality Improvement Program (CRWQIP) [5].

Thus, this milestone legislation will resolve a major international problem with Mexico and permit continued development of Colorado River water with reduced salinity impacts on the Basin.

Water Quality and Energy Development

The Colorado River Basin is a virtual storehouse of extensive, untapped fossil energy resources. It is anticipated that about 80 percent or more of the energy produced in the basin will be exported to other regions of the United States. The magnitude, processes, site location, and cooling methods for specific energy developments are expected to be centered around but limited by available water supplies in the basin. The development of powerplants, oil shale conversion plants, and coal gasification plants is expected to result in large depletions of water (up to 870,000 acre-feet by the year 2000) [6] and contribute to the salinity problem on the river. Energy development poses other water quality problems of associated municipal and industrial wastes, dissolved oxygen content, temperature, heavy metals, toxic materials, sediment, and bacteria. While these localized quality problems can occur throughout the basin, increased salinity from energy depletions and progressive reuse along the river poses further degradation of water before delivery to users in the Lower Basin.

Today, coal mining, coal conversion, and oil shale development for energy production are viewed as the most serious threats to water quality in the basin. Strip mining may seriously disturb patterns of drainage and surface runoff unless there is adequate, advance planning and effective controls. Salinity impacts can also occur from disposal of poor quality groundwater encountered in the mining processes. In many energy fields in the basin, groundwater aquifers interface with coal beds or oil shale deposits close to the surface. Removal of coal or oil shale by mining could change flow patterns in these aquifers and unwater wells in the area. Moreover, unless the strip mined energy fields are properly reclaimed and revegetated, excessive erosion rates could result. Water itself will play an important role in vegetative management and land reclamation in order to protect water quality.

Salinity Control in the Colorado River Basin

The dissolved constituent mineral concentrations in the Colorado River generally increase from headwaters to mouth. In the Western States, this increase is intensified because the soils and rocks are less weathered than in humid regions. Man's use of river water, primarily through irrigation and reuse, causes additional increases in concentration. In this process, evapotranspiration removes water from the soil, concentrating the salts, much of which appear in the return flows to the river. In addition to this salt concentrating effect, salt loading can occur through both mineral weathering and irrigation with the direct pickup of mineral salts that may reside in the soils and substrata. The primary salinity impact of energy development will result from salt concentration effects. Under Public Law 92-500, the Federal Water Pollution Control Act, the requirement for "zero discharge" is expected to prevent any degraded quality return flows to the river system. Thus, depletion of high quality water in the Upper Basin will result in salt concentrating effects primarily affecting downstream users. The basic processes of salt concentration and salt loading are depicted in the hydro-salinity system shown in Figure 1.

In overall terms, the salinity problem has been best dimensioned on the Colorado River. In the Colorado River Basin, high salinity levels in the lower reaches adversely affect nearly 17,000,000 people and about a million acres of fertile, irrigated farmland. Salinity concentrations are expected to have little adverse impact on instream uses such as recreation, power generation, and fish and wildlife. As a consequence, high salinity level is primarily an economic issue which results in measurable direct economic losses to Lower Basin water users and indirect economic losses to the entire economy of the region.

Over the years, there has been a man-induced, insidious rise in river salinity levels and accompanying economic losses. According to preliminary studies by the Bureau of Reclamation, water users in the lower reaches of the Colorado River are now incurring total damages estimated to be about $53 million per year and this is projected to increase to $123 million per year by the year 2000 if water resource development continues and no salinity reduction measures are instituted. A $230,000 per milligram per liter (mg/l) annual damage estimate is expressed in terms of agricultural, municipal, and industrial uses [2].

The Colorado River carries a salinity burden of about 10 million tons annually. If the salinity is to be kept at or below present levels in the lower mainstem, as recommended by the 1972 EPA Enforcement Conference [4], then about 2.5 million tons per year will need to be removed from the system each year. This may be regarded as a

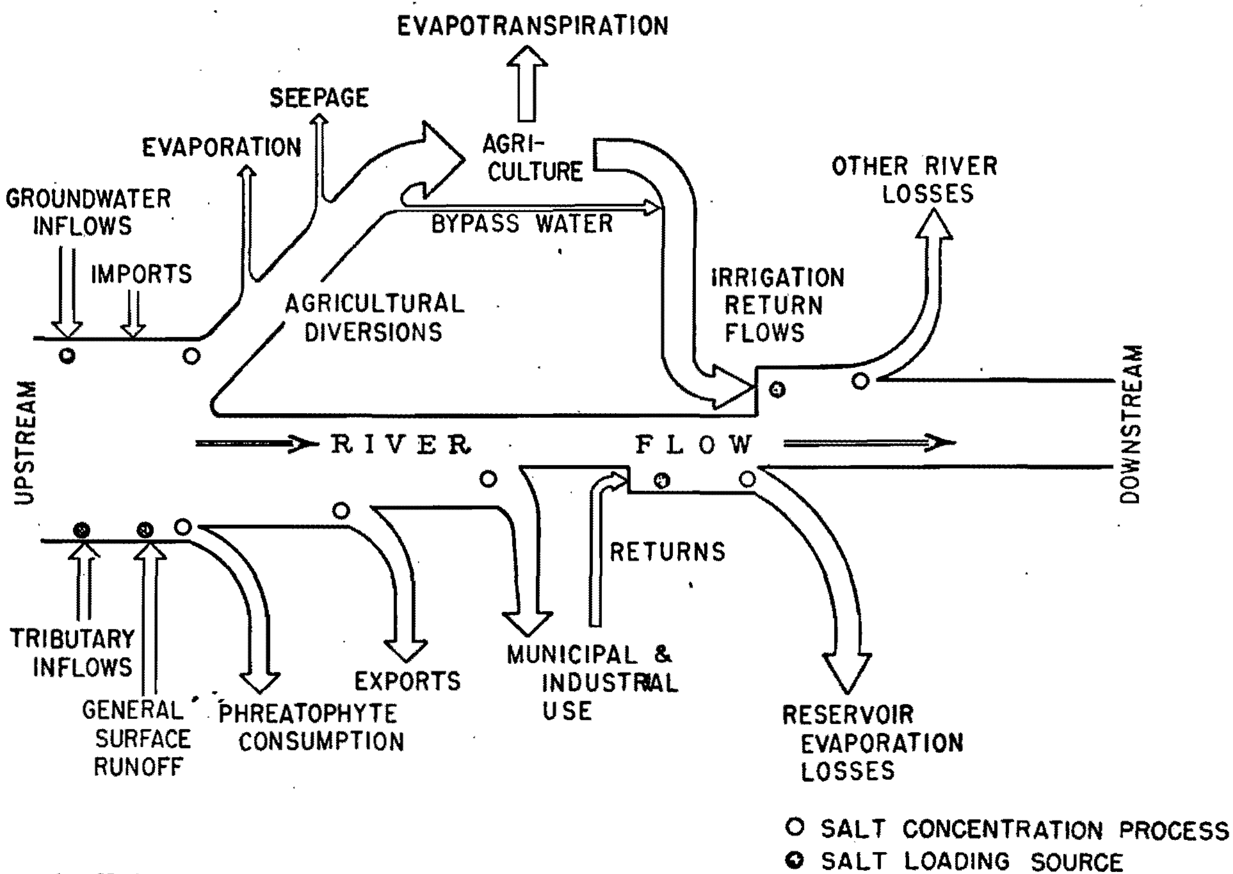


Figure 1. Hydro-salinity river system.

statement of the physical objective of a salinity control plan. However, control of the point, irrigation, and diffuse sources under program study would only provide a maximum reduction of about 1.6 million tons annually. This level represents a concentration reduction of about 150 mg/l at Imperial Dam under present conditions of development. Obviously, without additional effort, implementation of the control program will not meet the goals and schedule suggested from earlier enforcement efforts.

At the headwaters of the Colorado, the average salinity of river water is less than 50 mg/l. The salinity increases progressively until, at Imperial Dam, it now averages about 847 mg/l under present modified conditions.[1] Bureau of Reclamation projections of future salinity levels without a salinity control program suggest that average values of 1,152 mg/l or more will occur at Imperial Dam by the year 2000 [3]. Other agencies have projected higher salinity increases for the river (see Table 1). The overall salinity conditions in the river are closely related to and cannot be separated from future basin development plans with resulting water demands that are expected to exceed its dependable supply.

The Colorado River Water Quality Improvement Program (CRWQIP) under the Bureau of Reclamation, is only part of a growing basinwide water management strategy which must take into account not only salinity control but also future water supply and institutional considerations [1, 5]. Under the 10-year CRWQIP depicted in Figure 2, several non-term control plans have been under intensive study aside from the four units slated for construction. Current technology and management techniques have been examined for other potential salinity controls. The major categories of control under present study include: (1) Point source control, (2) Irrigation source control, (3) Diffuse source control, and (4) Total water management studies. Related activities, which are not a direct part of this program, include weather modification, sea water

[1] Present modified refers to historic conditions (1941-1972) modified to reflect all upstream, existing projects for the full period.

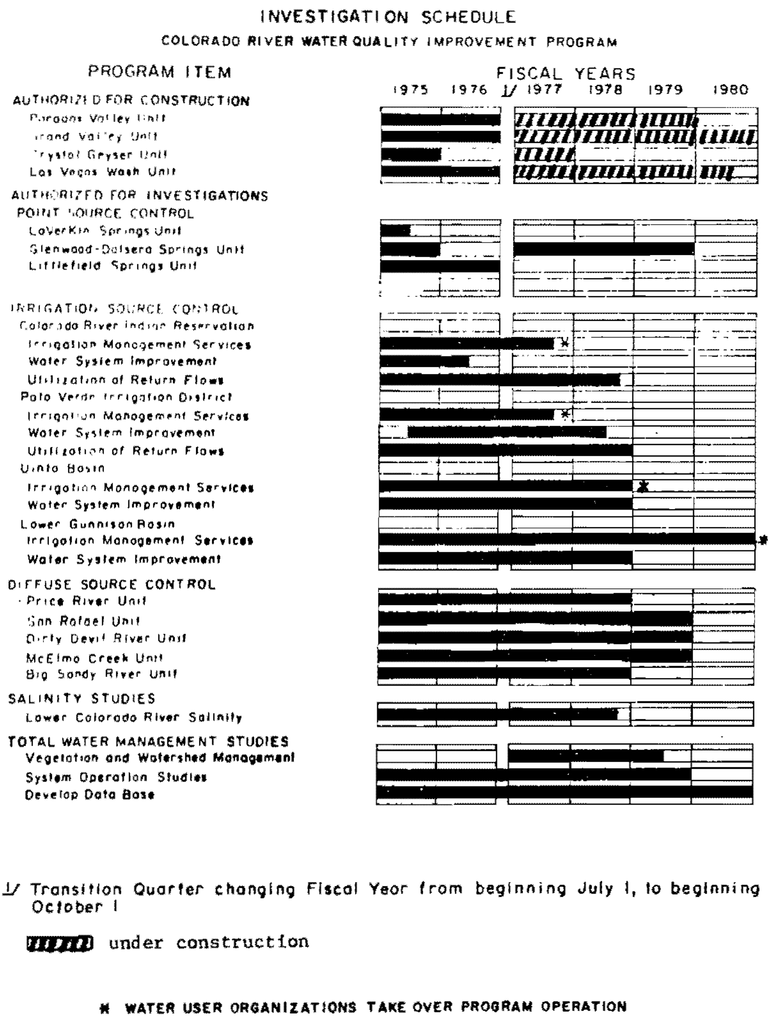


Figure 2. Investigation schedule.

Table 1. Projected concentrations of total dissolved solids (mg/l) at Imperial Dam.

Source	(Average Annual Values) Year				
	1980	2000	2010	2020	2030
EPA	1060	-	1220	-	-
CRBC	1070	1340	-	-	1390
WRC	1260	1290	-	1350	-
USBR	943	1152	-	-	-

EPA: Environmental Protection Agency, 1972
CRBC: Colorado River Board of California, 1970
WRC: Water Resources Council (Lower Colorado Region Comprehensive Framework Study), 1971
USBR: Bureau of Reclamation, 1975

desalting, and desalting geothermal brines--as dilution sources. Other salinity control efforts at the State and local level include: [5] The blending of Colorado River Water with other sources to serve southern California service areas, and [1] The proposed use of Palo Verde Irrigation drain water for powerplant cooling.

Under the CRWQIP program, examples of point sources include LaVerkin Springs and Crystal Geyser in Utah, Littlefield Springs in Arizona, and Dotsero Springs, Glenwood Springs, and Paradox Valley in Colorado.

Other significant salt loadings to the Colorado River from irrigated areas are contributed by the Grand Valley Basin in Colorado, the Colorado River Indian Reservation in California and Arizona, the Lower Gunnison Basin in Colorado, the Uinta Basin in Utah, and the Palo Verde Irrigation District in California.

Examples of diffuse sources are the Price, San Rafael, and Dirty Devil Rivers in Utah, McElmo Creek in Colorado, and Big Sandy River in Wyoming.

The locations of the control units involved in the program are shown on Figure 3.

The following tabulation shows the effects of implementation of the proposed control elements located in the Basin:

Unit	Estimated Salt Reduction (1000 tons/year)	Effect at Imperial Dam (mg/l)
Paradox Valley	180	-16
Grand Valley	200	-19
Crystal Geyser[a]	3	< 1
Lower Gunnison Basin	300	-27
Uinta Basin[a]	100	- 9
Glenwood-Dotsero Springs	200	-19
Price River[a]	100	- 9
San Rafael River[a]	80	- 7
Dirty Devil River	80	- 7
McElmo Creek	40	- 4
Big Sandy River	80	- 7
Las Vegas Wash	131-138	-13
Littlefield Springs	17	- 2
LaVerkin Springs[a]	103	-11
Palo Verde Irrigation District	23	- 3
Colorado River Indian Reservation	7	- 1
Total	1,644-1,651	-154

[a]Utah sites.

The implementation of all of the above elements can only provide part of the salt reductions considered necessary. Hence, the optimal attack on salinity control should not be confined to irrigated land, energy development, or even the extensive application of technology alone. Thus, eventually, most strategies will lead to the concept of total management of a basin's water and land resources.

Salinity Control in Utah

In Utah, the most advanced planning studies under the CRWQIP for salinity control are associated with the LaVerkin Springs Unit and the Crystal Geyser.

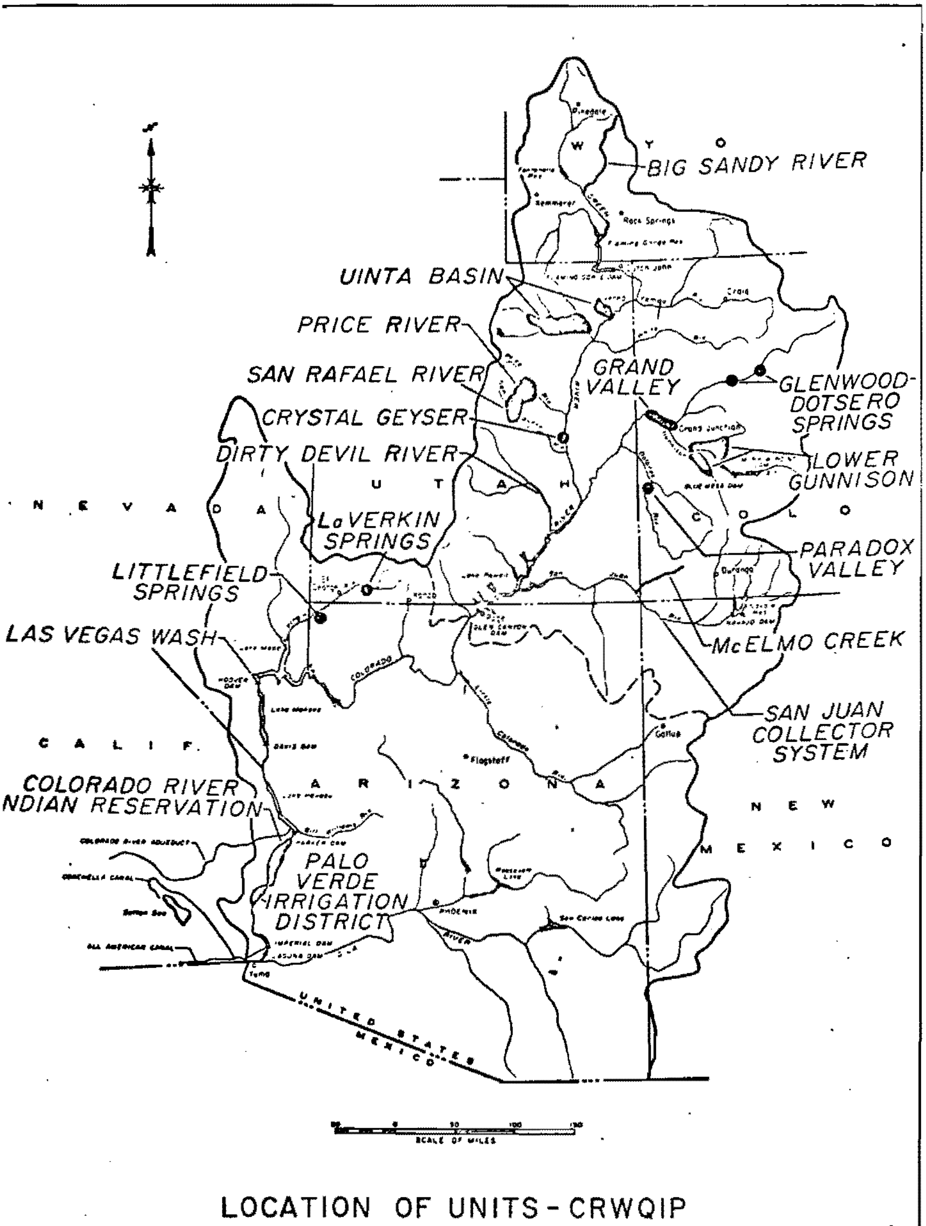


Figure 3. Location of Units -- CRWQIP.

The LaVerkin Springs are located in a 1,800-foot-long reach of the Timpoweap Canyon of the Virgin River near St. George in southwestern Utah (Figure 3). The springs discharge about 109,000 tons of salt each year. A feasibility study shows 103,000 tons of this salt could be removed annually by desalting using available commercial processes.

Crystal Geyser, an abandoned oil well, located just south of Green River, Utah (Figure 3), contributes about 3,000 tons of salt to the Green River annually. The basic plan of control is to build a wall or dike around the points of eruption to collect the discharges and then convey the water by pipeline to an evaporation pond for disposal.

Other opportunities for salinity control in Utah are focused on controlling the diffuse salt sources in the Price, San Rafael, and Dirty Devil Rivers as well as reducing the salt loading from Uinta Basin Irrigation.

All the planned salinity control units in Utah account for approximately 28 percent of the potential salt load to be removed under the CRWQIP. This removal of over 460,000 tons of salt could result in a 27 percent reduction in salt concentration at Imperial Dam as projected for the program.

Aside from established salinity control efforts in the state, the contribution of projected water depleting and salt concentrating effects of energy and other development must be taken into account in predicting total salinity impacts. Moreover, the vagaries of the hydrologic cycle in the upper basin states like Utah greatly affects salt concentrations downstream even more directly than projected water depletions.

Future Energy Development in Utah

Extensive activities are underway to develop the states' fossil energy resources. The location of potential energy fields of Utah including plant sites are shown in Figure 4. The energy fields include major

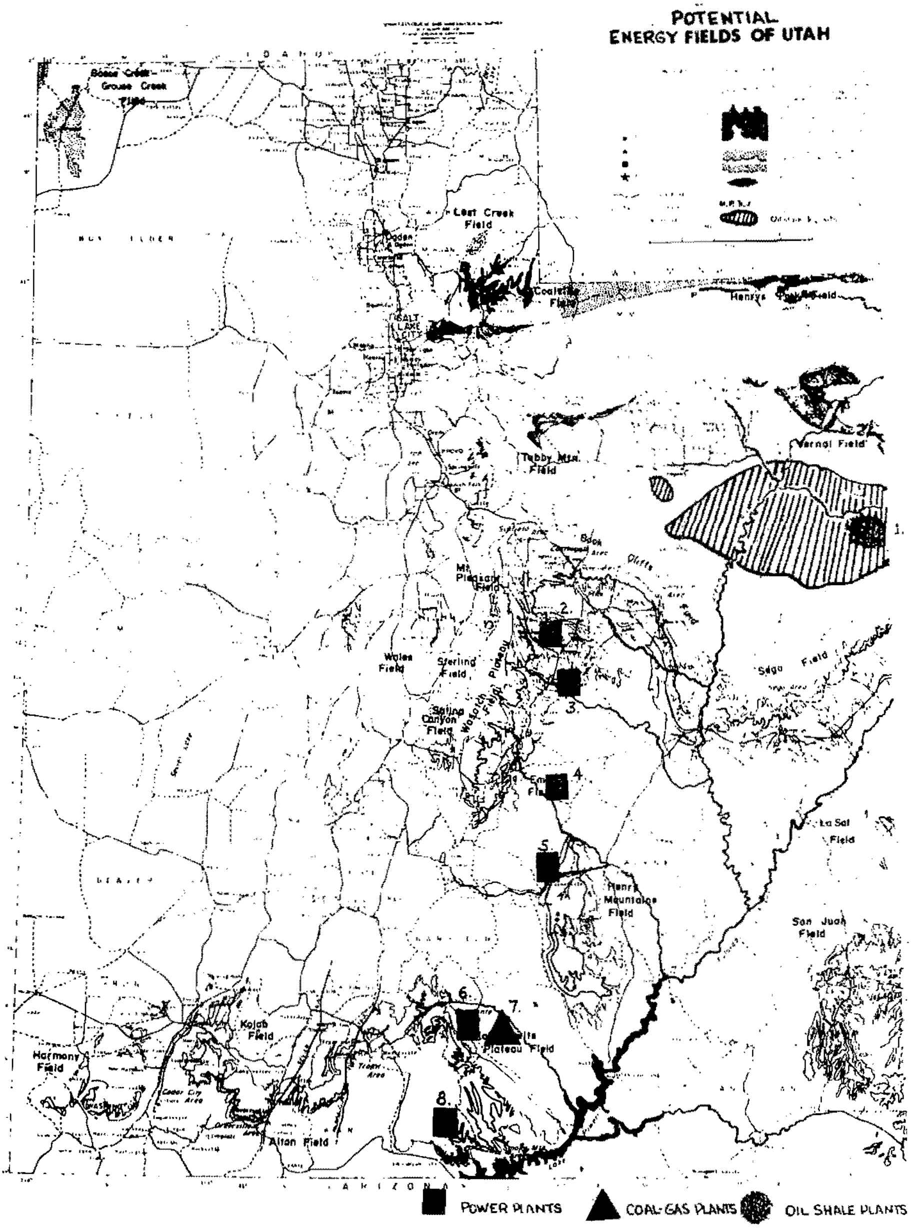


Figure 4. Potential energy fields of Utah.

coal zones and oil shale deposits. Plant sites, as indicated, represent either planned or potential developments for which leases, water supplies, and other specific requirements are actively underway or past studies have delineated. In Utah, most of the plant sites are clustered around tributary streams to the Green and Colorado Rivers. In view of the poor quality and low yield of the southern tributaries, plant water withdrawals are assumed to be taken from the mainstem flows and reservoir storage.

The water supply requirements to support the power plants, coal gas plants, and oil shale plants are highly dependent on specific site locations, processes used, cooling methods, and other parameters. However, in order to dimension the relative water requirement to support these planned or projected plants, the following unit factors were assumed except where specific amounts were established otherwise:

Coal-fired power plants	- 15,000 acre-feet per year per 1000 megawatt capacity (at 85 percent plant factor)
Coal gasification plants	- 15,000 acre-feet per year for a 250 million cubic foot per day plant
Oil shale plants	- 17,400 acre-feet per year for 100,000 barrels per day plant.

The following tabulation, keyed to Figure 4, shows the relative capacity and water requirements for the plants considered to be in operation by the year 2000 [6]:

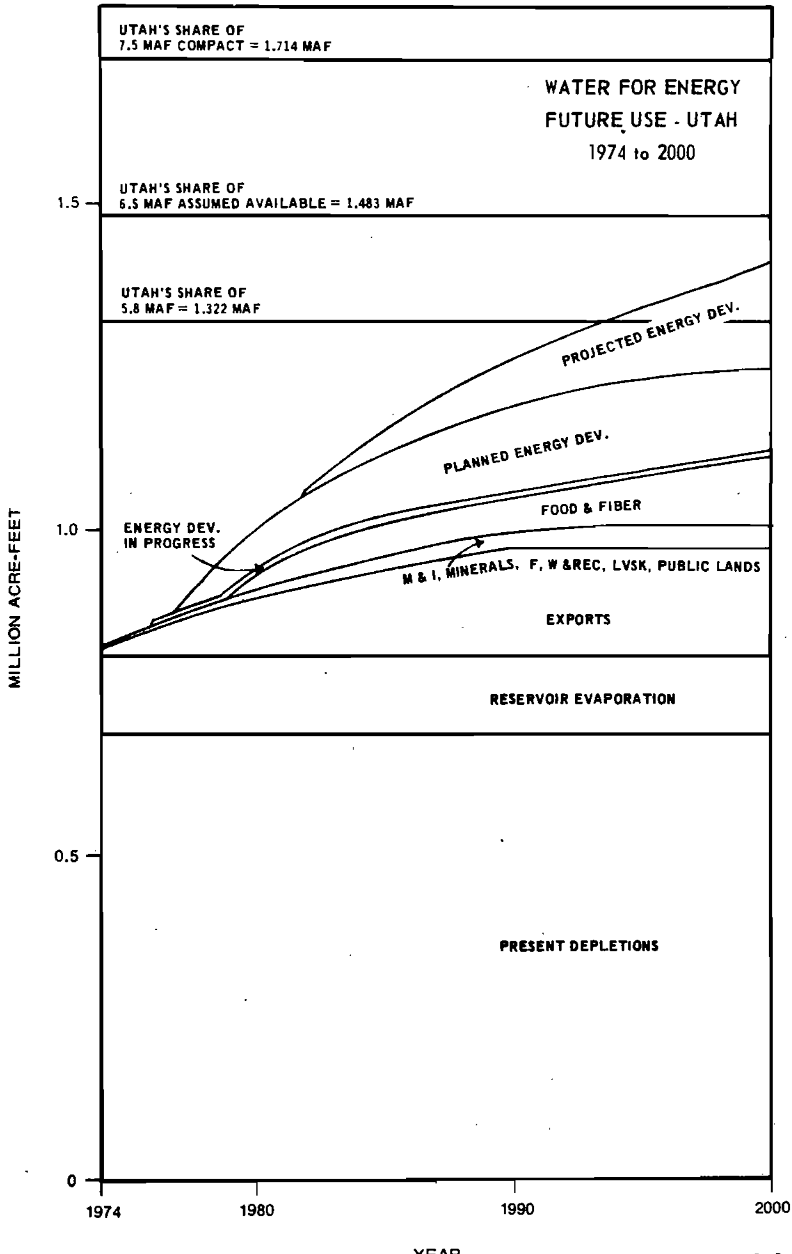
Location No.	Plant Name	Type	Plant Capacity	Water Required 1000 acre-feet/year
1	Phillips/Sun Oil, and others	Oil shale	300,000 barrels per day	46
2	Huntington Canyon	Power	1675 megawatts	17
3	North Emery County	Power	1125 megawatts	13
4	South Emery County	Power	830 megawatts	12

Location No.				
5	Fremont/Intermountain	Power	3000 megawatts	45
6	Escalante/Garfield County	Power	1000 megawatts	13
7	El Paso Gas Company	Coal gas	864 million cubic feet per day	52
8	Kaiparowits/ Resources, Inc.	Power	3000 megawatts	45
		Total water requirements		243

The magnitude of this projected water depletion only becomes meaningful when compared to present depletions and remaining available water supply. Figure 5 shows the relative importance of projected water depletions for energy development in the state. Framed against a conservative estimate of the total water supply available to the state (1.3 million acre-feet estimate), energy depletions are expected to exceed supply in the 1990-2000 time frame. It is also evident that the potential depletions for energy development may overshadow other water use categories of Food and Fiber, and Exports.

Salinity Impacts for Select Energy Sites in Utah

In general, salinity increases and economic impacts due to the projected water depletions singled out for energy development will be negligible within the state boundaries. Using the same "yardstick" as for measuring the present impact of salinity control measures, the following tabulation shows the net effect of energy-derived salinity increases as measured at Imperial Dam on the Colorado River:



Source Reference [1]

Figure 5. Water for energy, future use.

Location No.	Plant	Type	Effect at Imperial Dam (mg/l)
1	Phillips/Sun Oil	Oil Shale	+ 2.1
2	Huntington Canyon	Powerplant	0.7
3	North Emery County	Powerplant	0.6
4	South Emery County	Powerplant	0.5
5	Fremont/Intermountain	Powerplant	2.0
6	Escalante/Garfield County	Powerplant	0.4
7	El Paso Gas Company	Coal gas	1.5
8	Kaiparowits/Resources, Inc.	Powerplant	1.2
Total			+ 9.0 mg/l

In order to make a useful comparison to the salt reduction effects of the basinwide salinity control program, these salinity increases are based on present modified flow conditions on the river. Thus, the cumulative salinity effects of energy development measured against present control efforts appear to be of significant proportion. The total annual equivalent costs for this magnitude of salinity control can be compared to preliminary cost estimates developed for the four authorized salinity control units. Consequently, the present clean-up costs to offset the cumulative salinity impacts of energy development in Utah may vary from approximately 0.9 to 3.6 million dollars per year. These costs could vary significantly depending on the location, capacity, and type of control processes utilized.

It must be reemphasized that numerous assumptions and approximations must be made in attempting to quantify the future salinity impacts indicated above. Each energy site, for example, may have several different sources of water supply or may utilize new technology for cooling or processing to minimize water use.

At present, energy developers are using or obtaining water rights from the private sector or purchasing water from Federal water marketing agencies such as the Bureau of Reclamation. The purchase of agricultural water rights by energy interests will be yet another factor in affecting salinity impacts. Although the extent of this conversion activity is difficult to determine, it is conservatively estimated that 5 percent of current agricultural water supplies in Utah will have been converted to energy use by the year 2000 [6]. Utilization of local ground water supplies as an interim or conjunctive supply is another factor in determining future water depletions and accompanying salinity impacts. In Utah, the state's surface water supply is already overappropriated [6]. Here, water rights exceed not only the present water use but also the long-term potential water supply. As a consequence, there is no meaningful way of reconciling individual appropriations or group appropriations with present water use figures. In addition, Federal Reserve rights, water requirements for Indian Tribes, and water needs for environmental purposes such as quality, wild and scenic rivers, recreation, and fish and wildlife must also be addressed.

Aside from the complexities of water rights and cumulative depletion schedules, the physical constraints on the river system also tend to make salinity predictions a subjective process. Salinity impacts of energy development could be easily overshadowed or masked merely by excursions of water supply outside of normal or average hydrological patterns. The referencing of salinity impacts to the Imperial Dam in the lower basin also provides about a 3-year travel time before salinity impacts from depletions in Utah may be measured. In addition, the large reservoirs in the Colorado River Basin such as Lake Powell and Lake Mead also provide a great smoothing or averaging effect on incremental depletions upstream to further mask the specific impacts of chemical or mineral pollutants.

Efficient Use of Water for Energy Production

While water rights, allocations, hydrologic variations, and physical river system constraints complicate salinity impact analysis, future salinity control strategy will examine the prospects for efficient use of water for energy production.

At the present time, the price of water per se does not appear to promote more efficient use of water in energy development. Typical contracts already negotiated for energy use water, subject to Federal pricing, show a low average price of about \$7.00 to \$8.50 per acre-foot a year. Obviously, cost allocations of existing reservoirs originally built for irrigation supply do not reflect higher-valued energy use. Moreover, the relative cost of water being a small percentage (less than 1 to 2 percent) of the total energy production cost in order to produce a megawatt, barrel of oil, or cubic foot of gas does not necessarily encourage water use efficiency.

In view of the projected 243,000 acre-feet of water for energy development in Utah, more efficient use of that water could provide many dividends. Since more than half of this amount is for cooling purposes, salinity impacts of those depletions could be minimized if water of degraded quality was used or water recycling techniques were employed.

In any case, the future price of water for energy development will surely influence the efficiency of its use and its salinity impacts on the river system.

Summary and Conclusions

1. Salinity control legislation and Federal expenditures to construct control units in the Colorado River Basin place new impetus to improve total management of energy, land, and water resources. Moreover, additional management effort and incentives are needed to encourage private industry to share and expand water conservation techniques to minimize cumulative economic and environmental impacts on the river system.

2. In Utah, energy development will take a large proportion of remaining Colorado River allocations. The depletion of high-quality water from the Green and Colorado Rivers is expected to have significant salinity impacts downstream as compared to present control efforts and conditions.

3. The efficient use of water for energy development can be promoted by appropriate water pricing or other institutional means. Effective management will allow energy development to proceed, with

conservation of freshwater to meet other uses and minimal contribution to salinity in the Colorado River.

4. Salinity control strategy must not only take existing sources of salinity into account but seek out new ways of minimizing impacts of large-scale, freshwater developments for energy development.

5. Federal, state, and local encouragement should be made to promote the use of water of degraded quality to support energy development not only in Utah but throughout the Colorado River Basin.

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ENERGY AND AGRICULTURE

by

C. Booth Wallentine*

Ladies and gentlemen, Mr. Chairman and fellow panelists, I appreciate the opportunity to participate in this water seminar today. Some of the top water resources experts in the nation are in this room. We in agriculture have great respect and appreciation for you.

I believe it accurate to say that few subjects in Utah's history have evoked so much discussion, and frequently controversy, as water, or the lack of water. Throughout much of the nation today there are concerted efforts to improve water quality through control of heavy flow runoff waters. But here in Utah our concern is how best to spread our meager supplies over the maximum amount of land or other uses.

Farmers and ranchers in Utah have always competed and sometimes cooperated with each other and with municipal uses for these meager water supplies. Out of this competition and cooperation has come one of the modern world's most extensive systems of storage, conveyance, and distribution facilities for making best use of our water here in the arid west.

The use of water for hydroelectric energy has long been a factor in Utah. However, in many instances hydroelectric generation has been complementary to agricultural use rather than competitive.

Extensive development of energy from oil shale, tar sands, coal gasification, coal slurry transport systems, and other fossil fuel sources presents a new and very significant competition for our limited supply of water.

As it relates to energy development, I would note that agriculture is the leading user of petroleum and petroleum products. In 1974,

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agricultural users in America consumed 4 billion gallons of gasoline at a cost of $2,024,000,000. Farmers utilized 2.7 billion gallons of diesel costing $986,000,000 and they used 1.4 billion gallons of LP gas at a cost of $428,000,000. Thus, the total petroleum-based energy costs in 1974 for agriculture were $3,438,000,000.

To this total must be added nitrogen fertilizers which have as their basic building block natural gas. At this time more than 30 nitrogen fertilizer plants have been closed due to the lack of natural gas. Farmers also use many chemicals and sprays which are petroleum based.

Agriculture is also a major user of electricity, particularly in the west where irrigation is critical to our success. Electricity needs for irrigation have more than doubled in the past ten years.

Petroleum products are used also in the manufacture of tires. It requires 12 gallons of crude oil for a passenger car tire and 16-20 gallons of crude oil to manufacture a tractor tire.

Suffice it to say agriculture has a great need for more energy. However, in the west we are at the same time caught in the dilemma of which we need the most--energy or water. I will talk more about our water needs in a moment.

I believe these statistics illustrate how very real is the dilemma agriculture faces as we look at the tradeoffs between water for agriculture and energy for agriculture.

The recent energy crunch has effectively doubled the price most farmers must pay for these petroleum products. This has added greatly to the cost-price squeeze farmers and ranchers now face.

So agriculture fully recognizes the need to develop more energy resources. Moreover, farmers and ranchers are citizens first and farmers second. Our first interest is in the national welfare. For this reason, we in agriculture basically support further development of Utah's energy resources. But there are two very important factors which we believe should qualify this support.

The first is the impact of energy development upon our rural communities. Although it may not be popular to do so, I would raise a red flag on the notion that everyone will benefit from Utah's energy boom. This simply is not so. Particularly in the short run or mid-range period.

This is not an anti-development statement, but I believe it must be recognized that while some will benefit greatly through rapid development, many will also be economically injured.

Studies show rapid economic growth in a given area such as the Uintah Basin actually brings a lower standard of living to the bottom one-fourth or one-fifth of the population. This growth causes consumer prices to accelerate rapidly for everyone. Haircuts cost more, local services cost more, medical costs increase. Farmland values shoot up, but this only raises taxes and has little or no upward pressure on prices of farm products.

All these increased costs must be paid by the indigenous population as well as the newcomers. At the same time, at least in the short run, incomes for the prior residents, with the exception of a select few, do not keep pace with increasing costs.

As for the social changes in our rural communities when energy development comes to them, suffice it to say there will be difficult, if not sometimes distressing adjustments to be made. New political patterns will emerge. Additional recreational facilities, schools and other services will be necessary. But I am confident our rural community leaders are capable of giving guidance to these changes.

Again, I would emphasize this is not an anti-development statement. It is an appeal for full recognition that a substantial portion of the population does not benefit greatly from rapid economic development. Today in America our goal is to maintain the quality of life. Rapid development doesn't always do that.

I might note that a study has been underway at Utah State University to evaluate the impact of the energy boom on Utah's economic and social structure. What this development will do to water usage in the state is a key part of the study, as I understand it.

The second factor which must qualify support for extensive energy development in Utah is the specific impact upon our farm and ranch industry.

Energy development, with rapidly improving technology, may be able to discover alternative methods which do not consume so much water. Examples include air cooling rather than water cooling in some electrical generation plants, in situ extraction of oil from shale and surface transportation rather than coal slurry pipelines.

But for agriculture there can be no substitute for water. Much has been said about improved irrigation efficiency. According to data I have seen, Utah irrigators on the whole use water at somewhere near 30 to 35 percent efficiency. In Israel an efficiency of up to 90 percent has been achieved. Trickle irrigation, though not without some serious problems, has sharply boosted efficiency in California and Oregon.

For the Colorado River Basin there are at least two factors limiting greater irrigation efficiency. The first is that a very high rate of efficiency can reduce "washing" of natural salts until the salt-load buildup in the soil reaches toxic levels.

The second is that irrigation return flows from so-called "inefficient" upstream users often constitute a major source of the water for downstream users. As you might imagine, California users of the Colorado River do not look with favor upon sharp increases in the efficiency of Upper Basin users. And California, the nation's leading food producer, is overdrafting that state's groundwater at an estimated rate of one million acre-feet per year. (I'm not afraid of the political impact of suggesting California buy coal or other energy with water out of the Colorado allotment. It makes sense to me.)

In Utah, irrigation waters are the lifeblood of agriculture. Here in Utah, state water law, in effect, discourages farmers from utilizing their water more efficiently. And agriculture forms the economic foundation for most of the state's rural communities. It seems to me it is becoming increasingly clear that we must get back to basics and give agriculture greater consideration in the decision-making processes of our society. Society--four to five generations away from agriculture has lack of understanding of agriculture. We must once again realize that the food supply is priority one--in final analysis.

Approximately one million acres of irrigated cropland in Utah forms the base of operations for nearly 40 million acres of rangeland. Irrigated land produces winter feed, maintains our dairy industry, and provides farmsteads. More and more, it is becoming recognized that the western grazing industry, of which Utah is a vital part, is one of the most efficient production sources for animal protein.

Utah's estimated $340 million in annual cash receipts from agriculture are multiplied in the state's economy more than four times. This makes agriculture Utah's most broadly-based industry.

The U.S. Department of Agriculture's Economic Research Service has projected a 35 percent increase in domestic food needs by the year 2,000--just 26 years away. At the same time, USDA notes more than 2.5 million acres of farmland is converted to urban uses annually. This is partially offset by a 1 1/4 million acre annual reclamation of land, but the net loss each year is still 1 1/4 million acres--three acres a minute.

In recent years since market-wrecking government stocks of grain have been moved out of storage, agriculture has had increased incentive to produce for the market. This new incentive has brought most of the highly productive land in the midwest and the south back into production.

The Economic Research Service notes, therefore, that the west must play a key role in meeting future food needs. That means more water for agriculture--not less. By 1980--just five years away--the ERS predicts a 10 percent increase in demands for water for irrigation in the west.

Paradoxically--one federal agency calls for greater food production from the west while other federal agencies propose quantification formulas for federal water rights--under the Reservation Doctrine, which could effectively further reduce water for agriculture in the west.

A method to allocate precious water supplies among municipal, agricultural, and industrial users represents one of the greatest challenges we face in Utah. It will demand the wisdom of Solomon.

Water rights are basically a property right. And property rights have always been the very woof and fiber of our American system. The market system has served us well down through the years as an allocator of our resources.

And with all its imperfections, the competitive market must remain as the basic allocator of our presently adjudicated water in Utah.

Because there are so many external factors which affect the market for water, however, some restrictions may have to be placed upon the competitive market as an allocator of water, particularly for undeveloped, nonadjudicated water. Again, a call for the wisdom of Solomon. With our changing social pressures on what have been traditional water rights, I foresee a possibility of a social demand for putting water resources back into agricultural uses--perhaps by government first with little regard for the market system.

Given the present price structure for farm products, agriculture cannot hope to outbid energy companies for water. A $20 per acre-foot annual cost for irrigation water would represent a substantial investment for a farmer. But a utility company can recover that same $20 per acre-foot cost with a charge of 1 mill per kilowatt-hour--a relatively insignificant amount.

Clearly, I have offered more questions than I have answers. One thing appears certain, however--the energy crunch is a long term problem.

The energy problem comes at a difficult time in America. Our economy is wracked with unprecedented peacetime inflation. We are also locked in a difficult recession and virtually all segments of our economy face shortages. This is a most crucial combination.

At the same time, world food needs are expanding even more rapidly than energy needs. On that point these two facts stand out: First, each 24 hours there are an estimated 10,000 people who die of malnutrition or starvation throughout the world, and secondly, it's a true statement to know that 4 percent of the American population (farmers and ranchers) produce enough food to supply 23 percent of the world.

During a recent visit to New Orleans, I was impressed with information received that some of the many foreign ships waiting in the Mississippi River had waited as long as 25 weeks for a load of American grain. Clearly, the world has great need for the produce of our land. In the same opportunity, I noted a vast number of oil tankers from foreign countries bringing oil to feed our hungry automobiles, farm machinery, and our vast industrial system.

The message is clear. America must maintain a viable and ever growing agricultural industry if we are to meet the challenges of world trade as well as more humanitarian considerations.

In summary, agricultural people recognize the ever-increasing pressure for municipal water. We do believe greater attention should be given to water conservation among municipal users. Conservation of water will, no doubt, someday soon be forced upon household users through the price they will have to pay for water.

Again, agriculture recognizes the need for expanded energy production. But it cannot come at the cost of dewatering our Utah farms and ranches.

We must not be so foolish as to sell off agricultural water at bargain-barn prices only to find a few years hence that the most pressing need is for food. There are a hundred years in Utah's unmatched system of irrigation water conveyances. Without use, these systems would fall into disrepair rapidly. It would not be an easy matter to open the headgates again, to say nothing of the tremendous logistical system behind modern agriculture.

Rather, our emphasis should be upon development of new water resources and better conservation of what we have. Agriculture will be willing to do its share to conserve water. But we must find some way to give farmers and ranchers economic incentives to conserve water through increased efficiency.

Above all, we sincerely hope there will not develop a head-on confrontation between food and energy--with your leadership, we are hopeful that will not happen.

Thank you for the opportunity to present these thoughts today.

THE POLITICS OF WATER AND ENERGY DEVELOPMENT IN UTAH

by

Gordon E. Harmston*

I feel like a rookie being sent out to bat in the big game, after the two all stars, Senator Moss and Governor Rampton, were both called to Washington; particularly since the stands are filled with people more knowledgable than I.

I came to this job shortly after its creation and have tried to fill the shoes of a man much more qualified than I in every facet of water related subjects. I've done it by relying on a very excellent staff, some chosen by me; and it has been my privilege to bask in reflected glory like any good coach.

This reminds me of the story I heard as related by Governor Hathaway at one of the first Prayer Breakfasts given by Governor Rampton. It seems this rookie outfielder was having a horrible time in fielding his position. He lost a long fly in the sun; next he booted a grounder; and after an eternity the side was out. Coming to the bench, the coach told the rookie that he'd play his position the next inning to show him how. Going into the field, the coach promptly lost a fly in the sun; next a ball scooted between his legs. When the inning was over the coach came to the bench, threw his glove on the ground and said, "Hell, kid, you've got that position so fouled up nobody can play it."

I'm sorry I missed the morning sessions, but appearance before the Appropriations Subcommittee seems to be rather important to keep the money lifeline flowing. We are limited to one morning session to present the budget of each of the eight divisions with the department. Today was the last one, and now we wait with bated breath to see if we passed our test.

*Executive Director, Utah Department of Natural Resources.

I have been given the broad subject of "The Politics of Water and Energy Development in Utah," and I notice that you have almost every expert from my staff, from the federal agencies, and from the energy companies, so I shall not attempt to get into their subjects.

The fact that Utah is unique in the broad mix of its energy resources is a well known fact. Utah contains about 50 deposits of oil-impregnated sandstone, a substance better known as tar sand or bituminous sandstone. In the Uinta Basin, northeast Utah, seven deposits contain about 10.5 billion barrels of oil in place. In central southeast Utah, five deposits contain about 14 billion barrels of oil in place. The total oil in place in oil-impregnated sand in Utah is about 25.1 billion barrels, 98 percent of it in the twelve deposits previously cited. Utah contains 90 percent to 95 percent of the mapped U.S. resources in oil-impregnated sandstone, although exploration in other states is steadily adding to this resource.

To the end of 1973 Utah has produced between 325 to 340 million tons of coal coming mostly from Carbon County (77 percent) and Emery County (20 percent). Fourteen of Utah's counties have known reserves which total 24.35 billion short tons, not counting coal beds less than 4 feet and under more than 3000 feet of cover. Over 90 percent of this is contained in five counties, in order of abundance: Kane, Carbon, Emery, Garfield, and Sevier. Most of the coal in these five counties is excellent high volatile B or C bituminous coal, with low to medium ash and 0.4 to 0.8 percent sulfur.

Utah is high in production, almost 7.5 million tons of coal, occurred in 1947 during the post-war boom. Present developments indicate at least a doubling of production within the next few years, since Huntington Canyon is now on stream and the Emery County Project is moving along nicely.

Utah's the fourth leading producer of uranium in the county, but produces less than 6 percent of it. In 1972 it produced 412,000 tons of ore containing 819 tons of U_3O_8. Utah is fifth in reserve tonnage, the ore grade is the richest in the nation, and the contained U_3O_8 places the state in fourth position. Again, this is only 3 percent of the national reserve. Uranium ore is mined in San Juan, Grand, Emery and Garfield counties.

About 40 percent of Utah lies west of the Wasatch "line" and is part of the basin and range geological province. This part of Utah, like Nevada and other western states, contains numerous areas with abnormally high geothermal gradients. The past year or two has seen intensive exploratory activity looking to exploitation of possible steam or hot water fields.

About 6100 square miles of northeast Utah is underlain by oil shale of the Green River formation. However, oil shale of maximum grade and thickness is concentrated in an oval-shaped area covering about 1200 square miles of east-central Uintah County adjacent to the Utah-Colorado boundary. It is in the heart of this area that two adjoining test tracts were leased by the U. S. Department of the Interior in March and April 1974. On a per barrel basis the $120 million bid for these two tracts greatley exceeded bids for Colorado oil shale tracts.

Utah's resource in oil shale has been variously estimated from 900 billion to 1.3 trillion barrels of shale of all grades. The Utah Geological Survey estimates that within the optimum area of oil shale of 25 gallons per ton, 25 or more feet thick, there are between 90 and 115 billion barrels o oil. This is about 15 percent of the total U.S. resources in good grade oil shale.

Utah is unique in having sizable amounts of state-owned lands in the area of potential oil shale development. Virtually all of this is under lease at present. If Utah is successful in obtaining ownership to additional lands to which it is entitled in this area, the state will control a major portion of the commercial-grade oil shale within its borders, including most of that suitable for open-cut mining.

Any discussion of Utah's resources would not be complete without reference to the $80 billion worth of minerals in suspension in the Great Salt Lake, and the successful conclusion of our suit against the federal government over the relicted lands. That means the 606,000 acres of the lake bed, 396, acres of relicted lands, and 330,000 acreas of wildlife areas on the east shore are now firmly in state ownership. If we are successful in our present suit over the 157,000 acres of shale oil lands, we will be a rich landlord indeed.

You have all read of the strong possibility of oil being found under the bed of Great Salt Lake. Amoco Oil Company is presently planning two platforms for deep tests of the sedimentary beds.

One other important and large scale resource that might be exploited in the near future is the alunite bed near Milford.

Oil has been actively sought since 1891, and as more holes have been punched in our soil more oil and gas has been found. Present production is approaching 40 million barrels annually. Utah is relatively untouched compared to Wyoming where 75,000 wells have been drilled, or Colorado with 8,000. We have 4,000. Unfortunately most of our oil is in very deep zones overlain by rocks, which makes drilling very expensive. However, the increased price of crude is causing increased activity and new fields are being discovered and old ones expanded. New technology is also important, since the Altamont and Bluebell fields could not be commercially exploited when first discovered in the early 1950's.

In this regard, a very exciting possibility of a new large-scale petrochemical industry in the Uinta Basin is being explored. A research effort is being readied to put a package together showing industry that the Altamont crude provides one of the finest petrochemical feed stocks in the world. This comes at a rather appropriate moment since a grant has been obtained by the Ute Indian Tribe to bring Big Spring water to the heart of the Uinta Basin. This will make M&I water available to accommodate such an industry.

There are three ingredients to any successful commercial process: the resource itself, the capital requirements, and the political climate or the will of the people. I think we have all three, though indiscriminate development is precluded by a shortage of water; so very careful planning is mandated, with plenty of flexibility.

I'm sure Booth Wallentine pointed out that agriculture will move over and share to a degree; but we will not sacrifice our agricultural base on the energy altar. The importance of flexibility is underscored when we look back a few years to see the Central Utah Project concentrating on exporting water to the Bonneville Basin. We feel the Bonneville Unit is still most important, and are anxious for its completion; but our new imperative is for satisfying the in-basin requirements of the Uinta Basin, Carbon, Emery, and San Juan. This is why we are trying so hard to get the Upalco, Jensen, and Uintah units moving.

Utah is unique, not only in our resources but in our people. Though we are becoming more industry oriented, all the time we still retain close ties to the land and have not forgotten the harsh economic realities of our past generations. Thus, we will cooperate with industry to develop, but it must be done in such a way that our scenery is not destroyed, our air and water is degraded as little as possible, and our living style is not radically changed.

As we face the future we know that each day will bring new problems, because Utah will grow regardless of any action taken by any governmental body. The challenge is to control and channel growth. At least two members of the audience are from Wildlife Resources and their job is to minimize and mitigate, where possible, adverse impacts on wildlife. When we talk about efficiency of water use, it seems to result in inefficiency in maintaining a wildlife base.

We also have the legal problem where more efficient use of upstream water impairs the water rights of a downstream user. Implicit in these considerations is the broad public interest, since it is they who own the water and merely loan it for "beneficial use." New tools and new techniques must be explored to give our State Engineer all the means necessary to do his job. I'm sure Dee Hansen will point out that the hard job of trying to determine which of many competing industrial complexes will be given life is already a reality; and that, though he feels apprehensive to judge as Solomon, he must do so - subject, as always, to being sued. I think our growing dependence on a limited resource is highlighted by the fact that I'm sure Dee has been in court more times in the past two years than his predecessors in the previous ten.

In summary let me say we have the resource, we have the need, we have the will, and I think we have the ability to solve the vexing socio-economic and legal impacts. I believe the existence of these vast resources will be beneficial to the nation and to the state, and that their development will hasten solving the complexities involved in utilizing our water resources in conjunction with the reserved Indian rights under the Winters Doctrine, and the possibility of federal reservations being assessed.

I have one other thought that I would like to express. That is that I constantly go to meetings of agricultural interests and water interests and find the same people present. We are involved in a giant exercise of talking to ourselves when we really must expand our horizons to involve all units of government. Particularly should we involve that great group epitomized by the name "John Q. Public." We can only move as fast and as far as the public will permit. I cannot stress too highly the importance of getting public input, not only in soliciting the public's opinions, but in attempting to get those opinions tempered by a realistic rather than an emotional viewpoint.

INTEGRATED MEASUREMENT OF SOIL MOISTURE
BY USE OF RADIO WAVES

by

Duane G. Chadwick*

Introduction

Numerous methods exist for determining soil moisture. All of the methods found in the literature discuss the measurement of soil moisture at a point or at least in a relatively small volume. To obtain accurate information concerning the soil moisture over a large volume, numerous points must be sampled. The taking of numerous samples is laborious, requiring considerable time, effort, and money. A more desirable soil moisture measurement technique would be one that senses soil moisture over a relatively large area with comparative ease, accuracy, and economy. At the suggestion of a colleague, Joel E. Fletcher, an investigation into the possible use of radio waves for use in soil moisture measurements was undertaken. The feasibility of their use in making an averaged or integrated soil moisture measurement follows.

Surface Wave

Near the surface of the earth a radio wave is composed of two components, a surface wave and a space wave. The surface wave propagates with its lower edge in contact with the ground and can, therefore, only be vertically polarized since any horizontal electric field is short-circuited by the earth.

Power from a surface wave is dissipated in the earth's crust depending upon the characteristics of the soil over which the wave is

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propagating. Charges are induced in the earth due to the vertically polarized electric field of the surface wave. These charges induce a current flow through the earth which behaves like a leaky capacitor and can be represented by a resistance shunted by a capacitance (Terman, 1955). Based on this analogy, the electrical characteristics of the earth can be expressed by a conductivity σ, and a dielectric constant ϵ. Power is dissipated by the induced current flowing through the earth's resistance. This power loss accounts for the attenuation of the surface wave as it propagates.

Mathematical expressions describing the nature of the propagating surface wave, first given by Sommerfeld (1909) are discussed and simplified by Norton (1936). For an assumed flat earth, the surface-wave field strength can be expressed by

$$\text{Field Strength} = A\frac{Eo}{d} \qquad (1)$$

in which

Eo = field strength of wave at the surface of the earth at a unit distance from the transmitting antenna, neglecting earth's losses

d = distance from transmitting antenna

A = attenuation coefficient due to ground losses

The factor A is expressed by the curves in Figure 1. The numerical distance p for a vertically polarized wave is found by the relations

$$p = \frac{\pi d}{x\lambda} \cos b \qquad (2)$$

$$\tan b = \frac{\epsilon_r + 1}{x} \qquad (3)$$

in which

$x = 1.80 \times 10^{12}\ \sigma/f$

$\frac{d}{\lambda}$ = distance in wavelengths between sending and receiving antennas

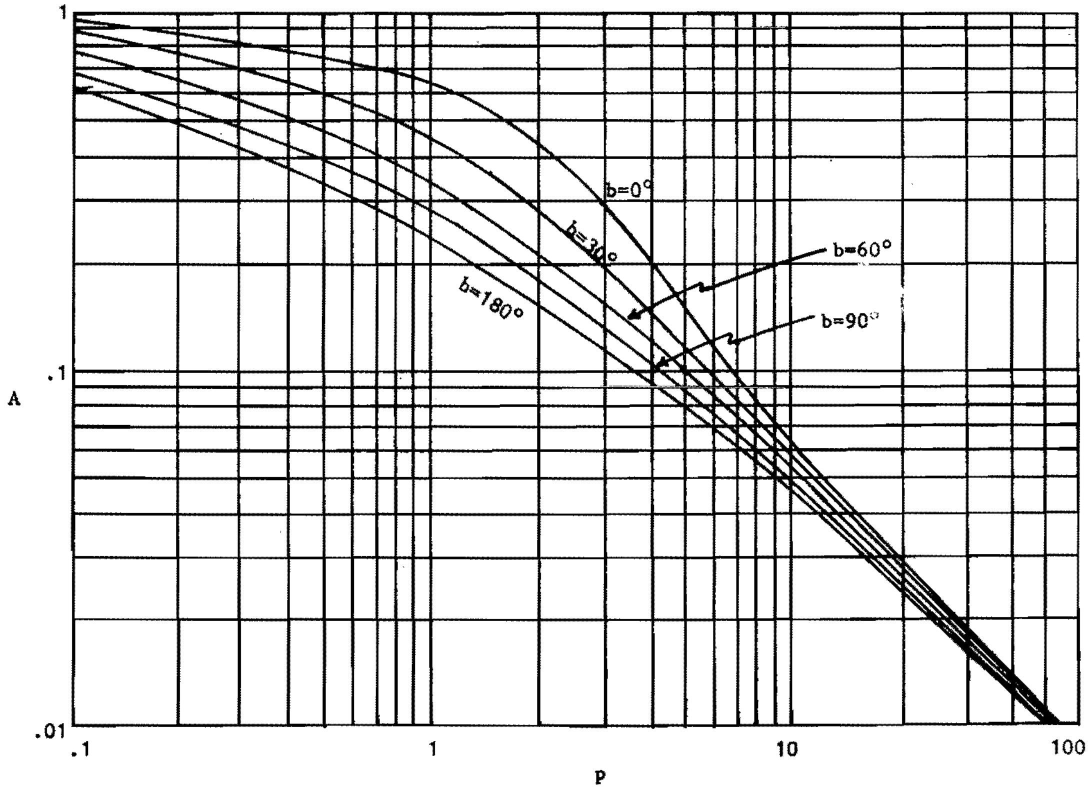

Figure 1. Attenuation coefficient (A) of surface wave which takes into account the ground losses (Terman, 1943)

σ = ground conductivity in mhos per cm

f = frequency in hertz

ϵ_r = dielectric constant of the ground referred to air as unity

The factor A is shown by Equations (1), (2), and (3) to be dependent upon the conductivity and dielectric constant of the earth, the frequency, and the distance from the transmitting antenna. If the antenna spacing and frequency are held fixed, the attenuation factor A is only a function of conductivity and dielectric constant. These parameters are known to be primarily a function of the water present.

Space wave

A second component of the radio wave of interest is the space wave. It is the vector sum of two separate waves. One is a direct wave between the transmitting and receiving antennas, and the other is a wave reflected by the surface of the earth before reaching the receiving antenna. An analysis of the effects of the space wave, shows that the field strength of the space wave will be negligibly small compared to the surface wave, provided the heights of the antennas used are small in relation to the distance between them. The effects of the space wave can therefore conveniently be neglected (Chadwick, 1973).

The foregoing discussion indicates there is a theoretical basis by which soil moisture can be determined by the attenuation of the surface wave. With favorable theoretical results thus obtained, consideration is next given to studying the depth that a radio wave can penetrate into the soil. For useful application of the measurements, radio waves should penetrate well into the root zone region.

Depth of Penetration

Current flow in a conductor is analogous to the problem under consideration. At radio frequencies, current flow is distributed so that most of the current flows near the surface of the conductor (ground).

This is because the inductance, and therefore, the impedance, is less near the surface than it is deeper in the conductor (ground), where more magnetic flux lines are linked with current flow (Terman, 1955).

With the surface of the ground at the $y = 0$ plane, the current distribution in the y direction would be given by (Jordan, 1950),

$$i = i_o e^{-\gamma y} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

in which i_o = current density at the surface, and

$$\gamma = \sqrt{j\omega\mu(\sigma + j\omega\epsilon)} \quad \ldots\ldots\ldots\ldots\ldots \quad (5)$$

The terms ω, μ, σ, and ϵ refer to transmitter frequency of measurement, permeability, conductivity, and the dielectric constant of soil respectivel Since the attenuation of current with depth is of chief interest, only the real part of γ is used. This is called the attenuation constant α. Therefore Equation (4) is rewritten as

$$i = i_o e^{-\alpha y} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

An arbitrary definition of the depth of penetration is the depth at which the current density is $i_o(1/e)$ or 37 percent of the surface current density i_o. This would occur at a depth

$$y = 1/\alpha$$

as can be seen from Equation (6). From Jordan (1950) the value of α can be calculated from Equation (5) and can be expressed as

$$\alpha = \omega\sqrt{\frac{\mu\epsilon}{2}\left(\sqrt{1 + \frac{\sigma^2}{\omega^2\epsilon^2}} - 1\right)} \quad \ldots\ldots\ldots \quad (7)$$

in which

μ = permeability of free space = $4\pi \times 10^{-7}$ henrys/meter

ϵ = $\dfrac{1}{36\pi \times 10^9}$ farads/meter

σ = expressed in mhos/meter

Using Equation (7) the depth of penetration of the radio waves can be calculated for any frequency and soil condition. For "wet" earth, with a conductivity of $\sigma = 10^{-4}$ mhos per cm and a relative dielectric constant $\epsilon_r = 15$, and "dry" earth, with $\sigma = 2 \times 10^{-5}$ mhos per cm and $\epsilon_r = 5$, the depths of penetration calculated to be about 2 and 6 meters, respectively. The soil-depth penetration can be shown to be independent of frequency above 30 MHz (Chadwick, 1973).

Some caution should be exercised in using the theoretical results regarding the depth of penetration since it was calculated with values of permeability equal to that of air. The presence of trace amounts of ferrous material will reduce the depth of penetration by the square root of the actual value of permeability compared to unity (reference value for air). Perhaps, more importantly, reflections from boundary layers beneath the earth's surface exist, since the earth's surface is heterogeneous. Any reflections that do occur reduce the depth of penetration of the radio wave.

For the foregoing reasons a quantitative value of the depth of influence of the propagated wave is difficult to predict accurately. From practical measurement experience, the system was shown to be most sensitive to the top 2-4 feet of the earth's surface. This is due chiefly to the tendency for the deeper soil to have a relatively constant degree of wetness and also the exponentinally decreasing effect of soil moisture on the radio waves that exist as a function of distance from the surface of the earth.

Physical System

In research studies reported elsewhere (Chadwick, 1973) the optimum antenna spacing, the antenna configuration, and the frequency of transmission are determined. These studies show that a transmitting and receiving antenna separation of 8-20 wavelengths are optimum. Theoretical considerations also show that the transmission frequencies of 27 MHz and 170 MHz can be used with equally satisfactory results.

Using these criteria, tests were conducted at both frequencies with an antenna spacing for 170 MHz of 15 meters, and spacing for the 27 MHz frequency of 95 meters.

An antenna configuration found to be satisfactory consisted of a sheet-metal ground plane 1 meter in diameter with a quarter-wave vertical antenna mounted in the center which was fed by a 50-ohm coax cable. The transmitting and receiving antennas are identical. An example of the equipment layout configuration for making soil moisture measurements at 170 MHz is shown in Figure 2.

A one and one-half watt transmitter was constructed for the 27 MHz band and a commercially available two-watt transmitter was used for the 170 MHz frequency. To help maintain consistent results, the transmitted power was maintained at a constant one-watt power output level for both frequencies.

The one-watt level was maintained by adjusting the battery supply voltage. The receiver consisted of an especially built field-strength meter which was broadly tuned to receive either 27 MHz or 170 MHz. More complete circuit details of the transmitter, receiver and antenna system are discussed in another report (Chadwick, 1973).

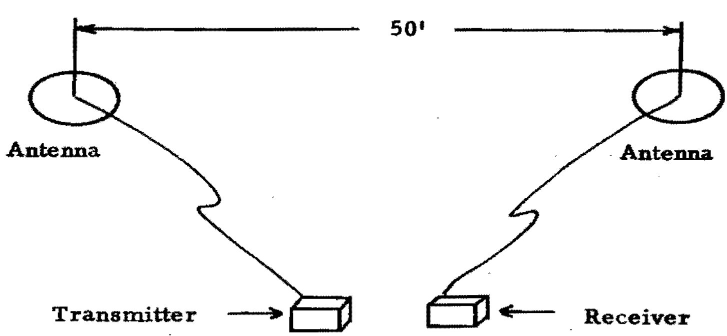

Figure 2. Field arrangement for operation by one operator. Use of 50 foot cables permits transmitter and receiver to be located adjacent to each other but out of line of the transmission path.

Experimental Results

Radio wave field strength versus applied water

One of the most direct approaches to observing effects soil moisture has on the field strength is to apply known amounts of water to a dry test bed and record the corresponding field strength. Figure 3 illustrates the results from this type of an experiment. The soil moisture was initially 6 percent by weight at the beginning of the test. Water was applied via sprinkling; the area sprinkled measured 25 ft x 50 ft square. The transmitter frequency was 170.255 MHz at a power of one watt into a 50 foot RG58 cable to a $\lambda/4$ ground-plane antenna. The field strength was observed to be linear with applied water until 0.64 inch of water was applied, thereupon a nonlinear increase in field strength was observed until 1.6 inches of water was applied at which point the test was terminated. The water was applied at a rate of .32 inch per hour. Virtually all of the water infiltrated as there was no runoff or appreciable collection of water on the surface. The following day the field strength had "sagged" from 17 mv to 14 millivolts. The second day after the test the reading was 13.4 millivolts at which point an additional .4 inch of water was applied increasing the field strength to 14.6 mv and 1/2 hour later it was 14.4 mv. Seven days following the initial test the field strength was 11.6 mv. Grass vegetation growing on the plot was relatively dormant during this period (July). The loss of signal with time was considered to be due to evaporation losses at the surface and drainage of water downward. As water goes deeper, its ability to enhance the radio signal diminishes. This phenomenon was discussed under the topic on depth of penetration.

Semiarid range land shown in the photograph of Figure 4 was selected as a test site for monitoring of natural soil moisture conditions. Annual precipitation at this Green Canyon site averages about 15 inches per year. Vegetation is principally composed of western wheat grass, yarrow, orchard grass, chicory, rabbit brush, and sage brush.

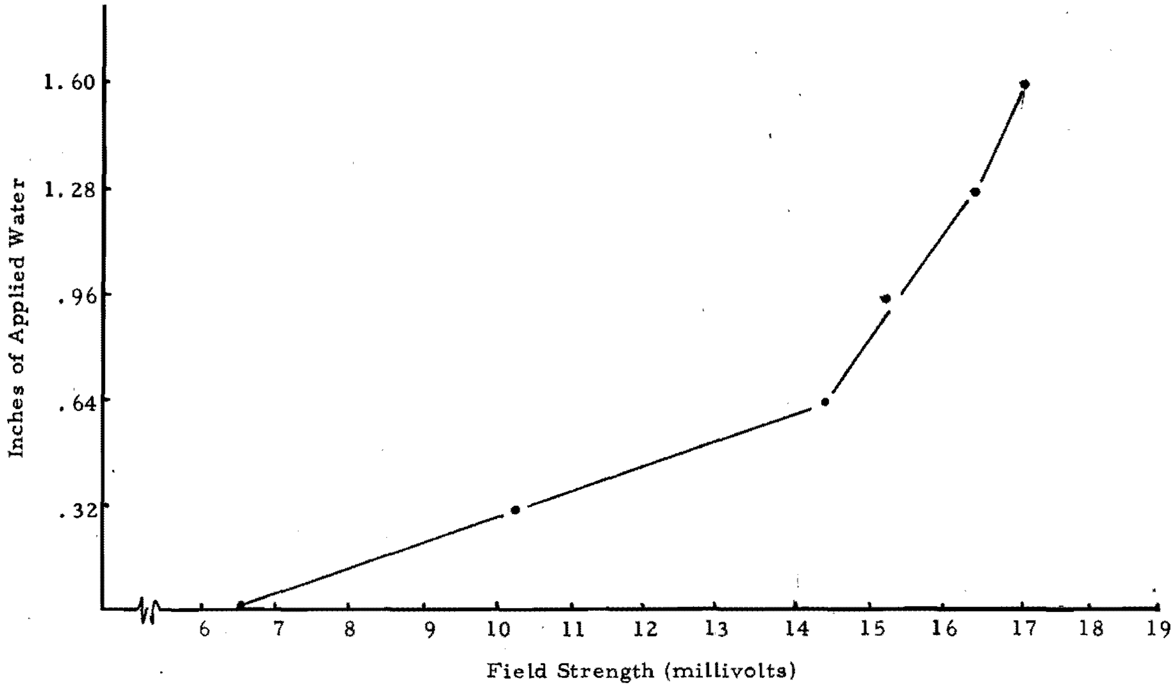

Figure 3. Plot of field strength versus inches of water applied over a 5 hour period.

Figure 4. Range land showing typical vegetation growth and 170 MHz antenna used in tests.

The top soil is about 12 to 14 inches deep. Under the top soil is a gravel-clay mixture which made difficult the obtaining of soil samples below about one and one-half feet. The top soil is classified as Greenville, gravely sandy loam. Soil moisture data taken by gravimetric measurements and also by field strength methods were obtained during several month-long periods spanning a 24 month period in time. Throughout all of the tests, the soil moisture as determined by weight maintained a constant relationship with the magnitude of the attenuated radio waves. For the data shown in Figure 5, the soil moisture was averaged over a two foot depth. Excellent correlation between the soil moisture measurement by weight, and soil moisture determination by radio wave attenuation measurements is illustrated. No values were observed at the extremities of the soil moisture range during this test but based on other data such as that of Figure 3, it is expected to behave as indicated by the dashed line extensions.

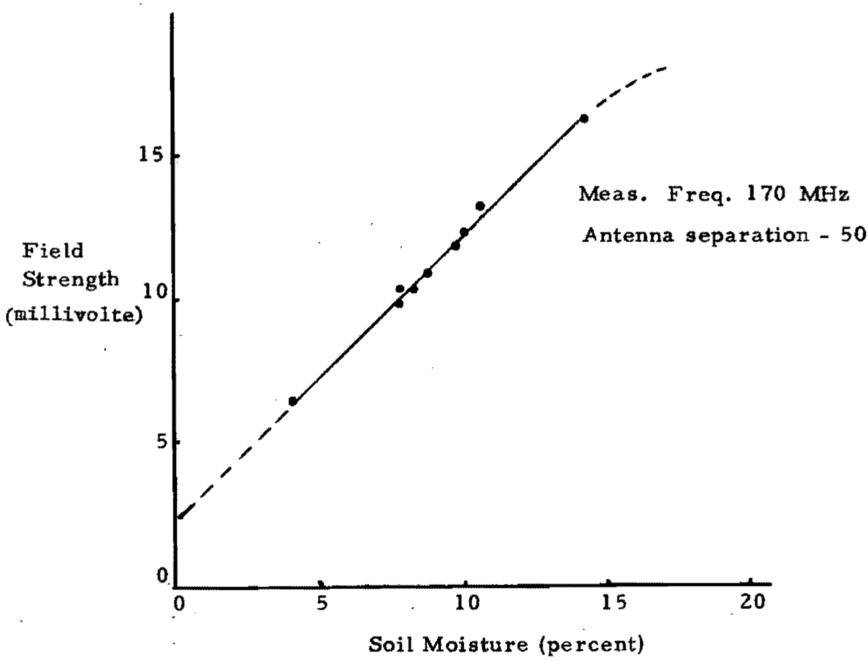

Figure 5. Green Canyon-North plot of soil moisture by gravity measurement versus electrical field strength.

Numerous other tests, similar to the one just described, were conducted at different sites. Typical results for these tests are illustrated in Figures 6 and 7. The data shown in these figures illustrate a generally good correlation between the strength of the received signal and the percent of soil moisture by weight, particularly so in Figure 6 where the soil was loose and soil samples were easily obtained.

In general it is felt that much of the scatter is due to the standard used for calibration. Generally two or three soil samples were taken

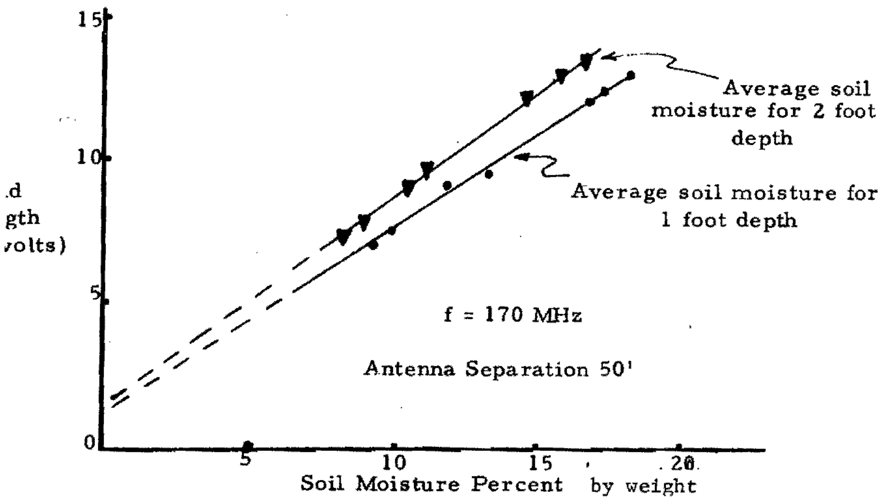

Figure 6. Grass plot on agriculture experiment farm. Soil is Millville silt loam.

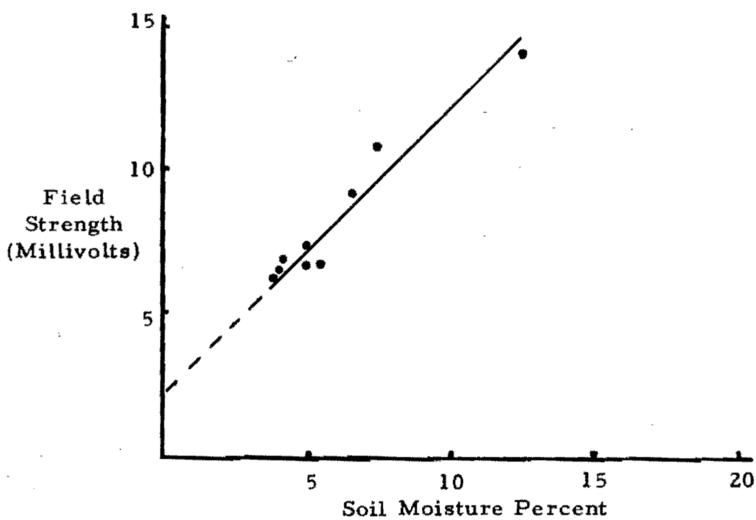

Figure 7. Green Canyon-South rangeland with grass and brush vegetation.

and averaged for the determination of soil moisture. Individual variations between samples were observed to be of sufficient magnitude to account for much if not all of the scatter observed in the data points. For a more accurate standard, probably 7 or more soil samples should have been averaged together. Such a technique would aid materially in getting more accurate results.

An interesting area that was studied was an apple orchard. The data were taken during the early part of the growing season before irrigation commenced, April 24 through May 15. During this period, the orchard grass grew to a height of about 9 inches. The antennas were situated parallel to the rows and equidistant between the rows. Antenna spacing was 50 feet and transmission frequency was 170 MHz. Measurement of soil moisture in the orchard presented some unique problems. Tree spacing was such that the water depletion was not uniform. Using a soil tube, it is difficult to get representative soil moisture samples under such circumstances. Soil moisture was observed to vary greatly from the center line between tree rows, to areas adjacent to the tree trunk where the irrigation ditches ran.

The unique properties of soil moisture averaging by the radio wave attenuation method was shown by taking several soil moisture readings in the orchard as follows: Four soil moisture radio readings were taken. The antennas were first placed on the center line between rows, next they were placed one-third the distance from the center of the row to the tree line. Third, they were placed two-thirds the distance to the tree line, and fourth the antennas were placed directly in line with the trees. The trees were in full leaf at the time and orchard grass about 8-10 inches high was located primarily under the trees where most of the moisture was found. The results are shown in Figure 8. Even though the interpath vegetation varies greatly and soil moisture varies 375 percent, the field strength varied only 30 percent. This should not be construed as an insensitivity to detect soil moisture, since previous data show a fairly linear correspondence between soil moisture and field strength over the range of general interest. The data presented

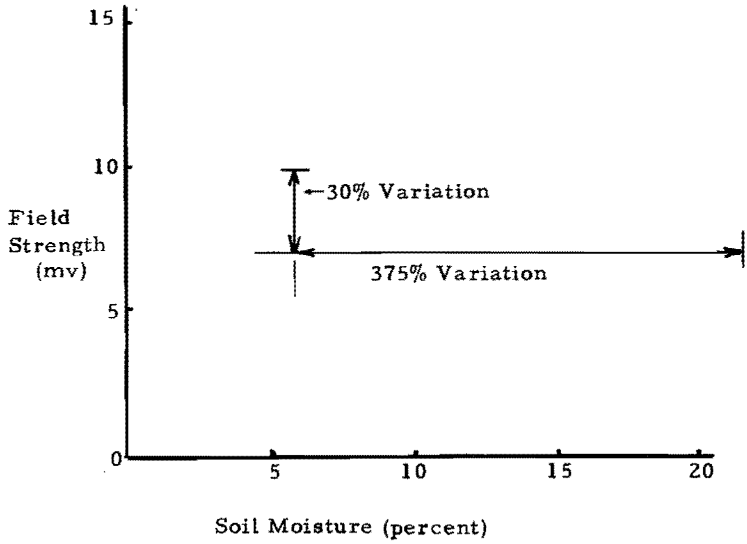

Figure 8. Soil moisture varies 375 percent between tree line and center line between trees. Radio field strength varies 30 percent over the same area. This illustrates the degree to which the field strength method can give the "average" value. It should not be construed as being an insensitivity to soil moisture changes which is elsewhere proven to have approximately a 1 to 1 relationship.

in Figure 8 does illustrate the degree to which the field strength method is able to average the variations of the soil moisture within the orchard. The data also illustrate that trees placed directly in line between the antennas do not greatly affect the signal strength. Numerous other soil moisture tests were made on several other test sites giving essentially the same results as those presented. Invariably the results were representative of soil moisture except where rank vegetative growth existed. The nature and magnitude of this problem are discussed in the following section.

Effects of vegetation on field strength

Unfortunately, dense green vegetation can have an adverse effect on soil moisture determinations by the use of radio waves. The more dense the vegetation the more the signal strength is attenuated independently of soil moisture. The reason for this attenuation is difficult to analyze theoretically in a quantitative manner. In general terms it is known that green plants will tend to short out the electric (E) field since the vertical standing plant and the vertically polarized wave are in the same plane. Since the E field is partially terminated in a conducting corn stalk for example, energy losses occur since power can be absorbed in the corn stalks.

The attenuation of the field strength in this manner can lead to the impression that the soil is dry when in fact, the reduced signal is caused principally by the presence of vegetation. To date this problem is not solved. There are several ways to partially overcome the problem, however, and several observations are made concerning them. Much vegetative cover is relatively constant in amount, e.g., an orchard. In situations of this nature, the effect is present but constant and therefore its effect can be ignored as it is eliminated by the calibration process. Some types of vegetation do not seriously affect the signal. This includes orchards, range lands, and crops that aren't too dense. The type of vegetation where the most noticeable adverse effect occurs is the dense agricultural crops like mature alfalfa, or corn. [1]

An experiment was conducted in order to illustrate the magnitude of the effect that mature, green rangeland grass had upon the signal strength, similar to that pictured in Figure 4. Initially the signal strength was 4.4 millivolts, the antenna separation was 50 feet, and the area to be mowed was 25 feet wide and 50 feet long between the transmitting and receiving antenna. The first 20 inch swath was mowed directly between the two antennas. Signal strength rose from 4.4 mv to 4.6 mv. A second swath was mowed and the field strength rose to 4.8 mv.

[1] In some instances the growth rate of rank crops might be measured on a day to day basis by the day to day attenuation of the signal. Such a serendipity effect has not been evaluated.

At this point, the mowed grass was raked and removed from the area. After removal the signal remained unchanged at 4.8 mv. Subsequent mowed swaths caused the signal to increase to 7.5 mv. Thereupon additional mowings reduced the signal slightly until it stabilized at about 6.8 mv. The exact cause of the increased interim signal noted, which was larger than the final value, is believed to be due to the channeling or "wave guide" effect of the signal caused by the standing grass. Reflections from the standing grass were of sufficient magnitude and proper phase such that some signal enhancement was probably obtained. This some phenomenon has been noted several times in similar tests, thus discounting possible instrumentation error.

The interesting fact that raking and removing the grass had no measurable effect is worthy of note. Apparently the amount of water in the grass is not sufficient to change the signal unless the grass is standing vertical and thus parallel to the E-field as explained earlier. Adjacent to the mowed area there was a bare 25 ft x 50 ft plot which had been cleared the year before. The field strength in that plot was 11.2 mv. When compared to the plot just discussed with a field strength of 6.8 mv, it is easy to tell how much water was used by the plants. The actual value in percent moisture can be read from the graph in Figure 7. This can be approximately related to inches of water with the aid of Figure 3.

<u>Instrument calibration</u>

The results obtained to date indicate that a laboratory calibration of moisture by weight will not hold for different types of soil and vegetation. This requires that each area where the instrument is to be used will need to be calibrated. This is not difficult, but it does require that two bench marks be obtained; "wet" soil condition and "dry" or plant stress conditions. Experience to date shows that thereafter a linear relationship exists between these two end points provided that vegetation is either not too dense or that it does not change in density a great deal. Normally the wet soil condition can be most easily obtained in the spring of the year or early summer after heavy rains or following an irrigation. The "dry" condition, of course, follows at a later date. Typically the "wet" soil signal is 2 1/2 - 3 times the "dry" soil condition so that if only one of the two bench marks are obtained the other can be predicted with fair accuracy. No attempt was made to calibrate moisture on a volume basis in lieu of a weight basis. From a theoretical standpoint, water expressed as a percent by volume should have a more nearly constant calibration coefficient for different types of soil. The degree to which this is achieved has not been determined.

Comparison of 170 MHz data with 27 MHz data

The results obtained for soil moisture measurement at two frequencies, 170 MHz and 27 MHz, were remarkably similar. The 27 MHz tests were conducted chiefly over a 95 meter course length. The 170 MHz extended generally to only 15 meters. The fact that partially different soil was being sampled, was considered adequate to account for deviations noted. A comparison of the field strengths of the two frequencies is illustrated in Figure 9. These data were taken at two widely differing locations over a three month period of time. The standard error between them is 1.1 millivolts. In terms of soil moisture, it is about 1 percent, i.e., 7 percent versus 8 percent soil moisture, etc.

Notes on operational procedures

Numerous additional experiments were conducted regarding both technical and practical aspects of soil moisture monitoring. The more important observations not previously commented upon are included here for assistance to those who may undertake such measurements.

1. If an antenna, transmitting or receiving, is too close to a fence or other metal object, the antenna which is normally omni-directional, may become somewhat directional and as a result the received signal strength will be accordingly affected. Some experimentation is necessary to judge the magnitude of the effect but at 170 MHz it is recommended

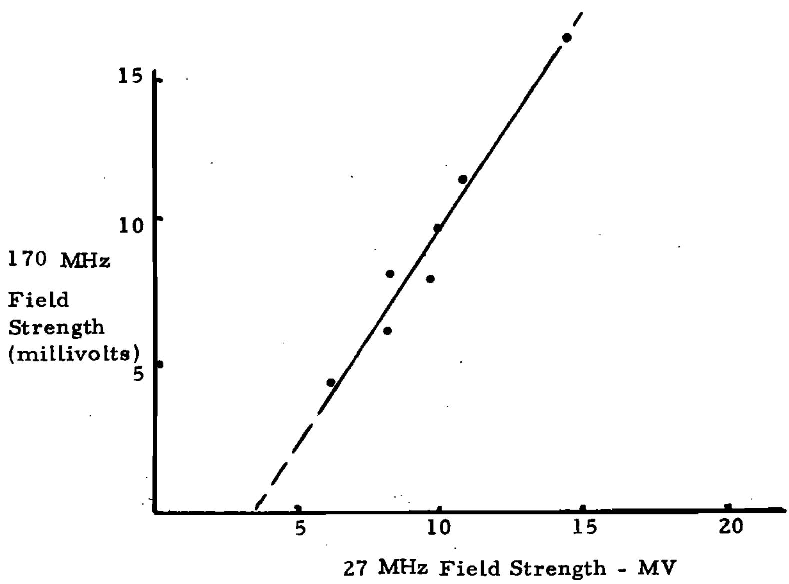

Figure 9. Plot showing comparison of 170 MHz versus 27 MHz signal strength. Data were obtained over a summer season at two locations, range land and at an apple orchard. Mean square deviations between two results is 1.1 mv. Had transmitter power or antenna spacing been adjusted slightly the line would pass through the origin.

the antenna be greater than 100 feet from large metal objects, etc.

2. A single operator can operate the transmitter and read the field strength at the same time if the antenna separation is 15 meters. The coax lead-in from each antenna should also be 15 meters long. In orientation, the tranmitter and receiver coax cables should form two legs of an equilateral triangle with the third leg being the 15 meter center line between the antennas. The operator is thus outside of the influence of the field of measurement. To further minimize the effect of the operator, he should squat or kneel at the instruments to

minimize the "antenna effect" he creates by standing erect. Also vehicles, metal buildings, etc., should be 100 feet or more from either antenna.

3. Normally two people are required to make field strength measurements at the 27 MHz frequency since antenna spacing is about 300 feet minimum and one person turns on and adjusts the transmitter power while the second person records field strength at the receiver.
4. The received field strength is fortuitously proportional to the radiated power squared, therefore, voltage measurement errors caused by power output variations is approximately reduced by a factor of two, e.g., if power output is 10 percent above normal received signal strength calculates to be 4.9 percent above normal. Despite this "advantage" care should be exercised to maintain the radiated power constant.
5. Accurate antenna spacing is important and for comparative measurements the antennas should be placed in the exact same spot each time the measurements are made.
6. The $\lambda/4$ antenna length is a fairly important parameter. It will not work well if bent, and it must be as near vertical as can be judged by the eye to work properly.
7. It does not matter appreciably if the antenna is wet or if it is raining at the time of the measurement.
8. The system is moderately sensitive to water distribution in the vertical plane. A more stable reading is obtained a few hours after a heavy rainfall when the soil moisture distribution is in a more stable state. This assumes that the original calibrations were also made with soil moisture in a quasi-stable state.
9. In vertically polarized antennas, the antennas can be elevated a quarter of a wave length above the surface of the ground to be measured if desired without appreciably affecting the field strength.

10. Technically, the operation of a transmitter to measure soil moisture should be licensed by the Federal Communications Commission, Washington, D. C.

Summary

The results of this research demonstrate that the presence of soil moisture increases the field strength in direct proportion to the moisture present. Linearity between field strength and soil moisture is maintained over a wide soil moisture range of interest coinciding with many plant requirements.

In order to make soil moisture determinations, propagated radio waves are launched from a transmitting antenna and detected some distance away by a receiving antenna. The measurement obtained can be considered to be an integrated value of soil moisture since it samples the entire region in a continuum between the antennas.

Since different soil types have different intrinsic values of dielectric, each soil type may require a separate soil-moisture/field-strength calibration. This is readily accomplished assuming a linear relationship exists in the soil moisture levels of interest.

A chief disadvantage of the vertically polarized radio wave is that its magnitude is diminished by green, rank vegetation. The attenuation is not serious if the vegetation lies close to the ground or is not too dense. Mature alfalfa or tall corn does not yield good results. Reliable results were obtained however in an orchard and on range land, pasture land, golf course, etc.

Soil moisture in the top 2 to 3 feet of the soil has the dominant effect on the received field strength. Exact depth of radio wave penetration depends on <u>magnetic</u> permeability of the soil and the "skin effect," an electrical phenomenon which causes alternating currents to flow on the surface of a conductor, viz. the earth. Probably in no event would depth of penetration be appreciable below 5 to 10 feet at the radio frequencies used in this research.

The theoretical mathematical expression shows that the radio waves attenuate in an exponential fashion with soil depth, therefore, the radio waves are more affected by moisture in the top of the soil mantle than they are at the deeper extremities of their penetrable range.

Incremental changes in soil moisture are readily detectable after each rainfall. The sensitivity of the system to rainfall can thus be of considerable benefit in assessing the effects of a storm. As a result of this information, irrigation practices could be adjusted to take economic advantage of such quantitative knowledge about the areal extent and the intensity of the storm.

The system works equally well at both 27 MHz **and** at 170 MHz. A minimum of 8 wave lengths spacing between transmitting and receiving antennas are required to give the maximum signal ratio for the wet to dry soil range.

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MUNICIPAL/RESIDENTIAL WATER USE IN NEW AND EXISTING URBAN AREAS

by

W. R. Kirkpatrick, B. C. Saunders, and D. W. Eckhoff*

Salt Lake County's population is projected to increase more than 250 percent in the next 50 years, and municipal/residential water requirements will show similarly dramatic increases. Of major importance for planning purposes is the determination of specific future water needs. In this regard, per capita water consumption is a major factor, inasmuch as future water needs will be the product of population times per capita consumption.

Presently, the distribution of water use in Salt Lake County is 44 percent for municipal uses (of which 11 to 15 percent is used for industrial and light manufacturing purposes) and 56 for self-supplied industrial use. These figures are based on the 1960 Harline determination and industrial (M & I) water use of 0.54 acre-feet per capita per year (afpcy) or 485 gallons per capita per day (gpcd).

Harline and others have projected significant increases in per capita water utilization, but there is no evidence to indicate any significant temporal increases. Historical data on municipal per capita water use from 1913 to 1969 indicate no long term upward or downward trend. Rather, the annual per capita water use quantities are cyclic about a mean of 0.24 afpcy (214 gpcd) and fall within a range of 0.20 to 0.28 afpcy. Table 1 shows the statistical parameters associated with annual water use data from time period 1913-1969 and 1945-1969. Municipal per capita water use in Salt Lake County has shown no historical dependence on the "time" variable during the 1913 to 1969 period. Periods

*University of Utah and Utah Water Resources Division.

Table 1. Annual per capita water use.

1913 - 1969	
Sample Size	56
Maximum	0.28 afpcy
Minimum	0.20
Range	0.08
Mean	0.240
Standard Deviation	0.023
Coefficient of Variation	0.10
Median	0.24
Modes	0.229, 0.253 (4 values each)
1945 - 1969	
Sample Size	24
Maximum	0.28 afpcy
Minimum	0.21
Range	0.07
Mean	0.246
Standard Deviation	0.019
Coefficient of Variation	0.08
Median	0.24
Mode	0.229 (3 values)

of low per capita municipal use have corresponded with periods of low water availability (droughts), and high per capita consumption has been associated with "wet year" periods (see Figure 1). These observations make it abundantly clear that short term trends (10 years or less) cannot be used with any degree of confidence in making long-range projections of per capita water use.

Other studies have shown that socio-economic conditions, such as property value and lot size, are major determinants of per capita water use. However, local factors also predominate and must be taken into consideration. At the present time universally reliable estimating methods are not available, and local investigations must be made.

It was determined in this study that homogeneous pilot areas could be used to develop usable socio-economic vs. water use relationships for local residential areas. It was first necessary to select areas with reasonable homogeneity (with respect to the socio-economic factors to be employed), and then to collect water consumption records from approximately 75 residences within each pilot area. To insure that accurate water use, demographic, and socio-economic data could be obtained, data on water consumption covered three year periods centering on census years.

Table 2 lists pertinent socio-economic parameters and statistical parameters for the four pilot areas. In this study the single family dwelling pilot area average water use values ranged from 0.178 to 0.305 afpcy, or 159 to 273 gpcd. These values include sprinkling use. Other studies have clearly shown that the economic level of the consumer, the climate, and the method of assessing water use charged (metering or flat rating) are major determinants of water use. These factors are significant in Salt Lake County and in other areas along the Wasatch Front. On the other hand, per capita water use is virtually nonelastic with price at present day and foreseeable future ranges of use charges.

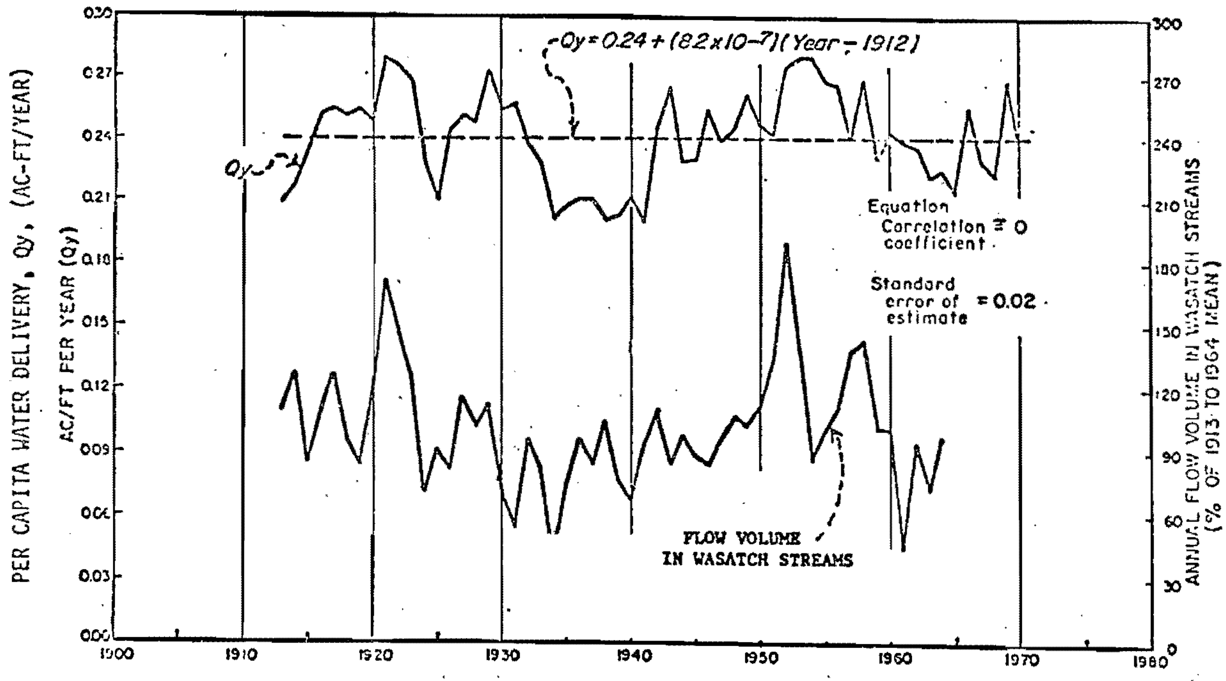


Figure 1. Historical trends in annual per capita water delivery and flow in Wasatch streams.

Table 2. Pilot area statistical parameters.

Study Area	1		2		3		4	
Period (years)	59-61	69-71	59-61	69-71	59-61	69-71	59-61	69-71
Socio-economic Parameter								
Persons/household	4.02	4.07	Not avail.	4.14	2.5	2.42	4.13	3.89
Property value ($1,000)	41.60	52.96	Not avail.	30.40	14.00	17.40	20.00	24.70
Mean income ($1,000)	18.00	34.03	Not avail.	15.15	5.97	9.90	7.55	13.17
Median income ($1,000)	-	30.52	Not avail.	13.70	-	8.62	-	11.96
Gross lot size (acres)	0.50	0.50	0.30	0.30	0.20	0.20	0.34	0.34
Study area population	-	626	-	1,565	-	12,000	-	3,080
Per capita delivery (ac-ft/yr)	0.282	0.305	Not avail.	0.178	0.231	0.234	0.181	0.181
Statistical Parameter								
Sample size	75	71	Not avail.	76	80	78	86	75
Maximum delivery (gpcd)	725	830	Not avail.	277	456	665	235	229
Minimum delivery (gpcd)	26	57	Not avail.	73	47	67	90	95
Mean (gpcd)	252	273	Not avail.	158	206	209	162	161
Standard deviation (gpcd)	119	110	Not avail.	39	89	106	32	31

For single family dwellings in Salt Lake County the most significant socio-economic determinants of per capita water use, Qy (afpcy), are property value, PV (in \$1,000), and annual income, I (in \$1,000). These two factors resulted in the best linear multiple regression, and income provided the best fit in simple linear regression. The two sets of equations are:

$$\text{1969-1971:} \quad Qy = 0.23 + 0.024\,(I) - 0.014\,PV$$

$$Qy = 0.147 + 0.0044\,(I)$$

$$\text{1959-1961:} \quad Qy = 0.196 + 0.035\,(I) - 0.013\,(PV)$$

$$Qy = 0.166 + 0.0062\,(I)$$

The majority of single family dwellings in Salt Lake County are associated with socio-economic conditions which indicate per capita water use in the range 0.15 to 0.32 afpcy, or 135 to 286 gpcd.

With increasing proportions of apartments and condominium complexes in the Salt Lake area it is important to consider the possible impacts of high density dwelling units on per capita water use. Sprinkling use is obviously attenuated, but other types of water use also appear to be reduced. The apartment complexes in Salt Lake County are estimated to have water use requirements averaging about 100 gpcd, or 0.11 afpcy.

Using the apartment and single family dwelling per capita use data obtained in this study, it was shown that population density, PD (person/acre) is an excellent determinant of per capita water use, Qy (afpcy) (see Figure 2). The relationship is:

$$Qy = 0.085 + 1.55\left(\frac{1}{PD}\right)$$

This equation shows a minimum requirement of 0.085 afpcy, or 76 gpcd. Thus, the minimum domestic (nonsprinkling) residential water use is estimated to be about 70 gpcd.

Conversions of agricultural lands to residential areas brings with it the question of impacts on water requirements. It is generally believed

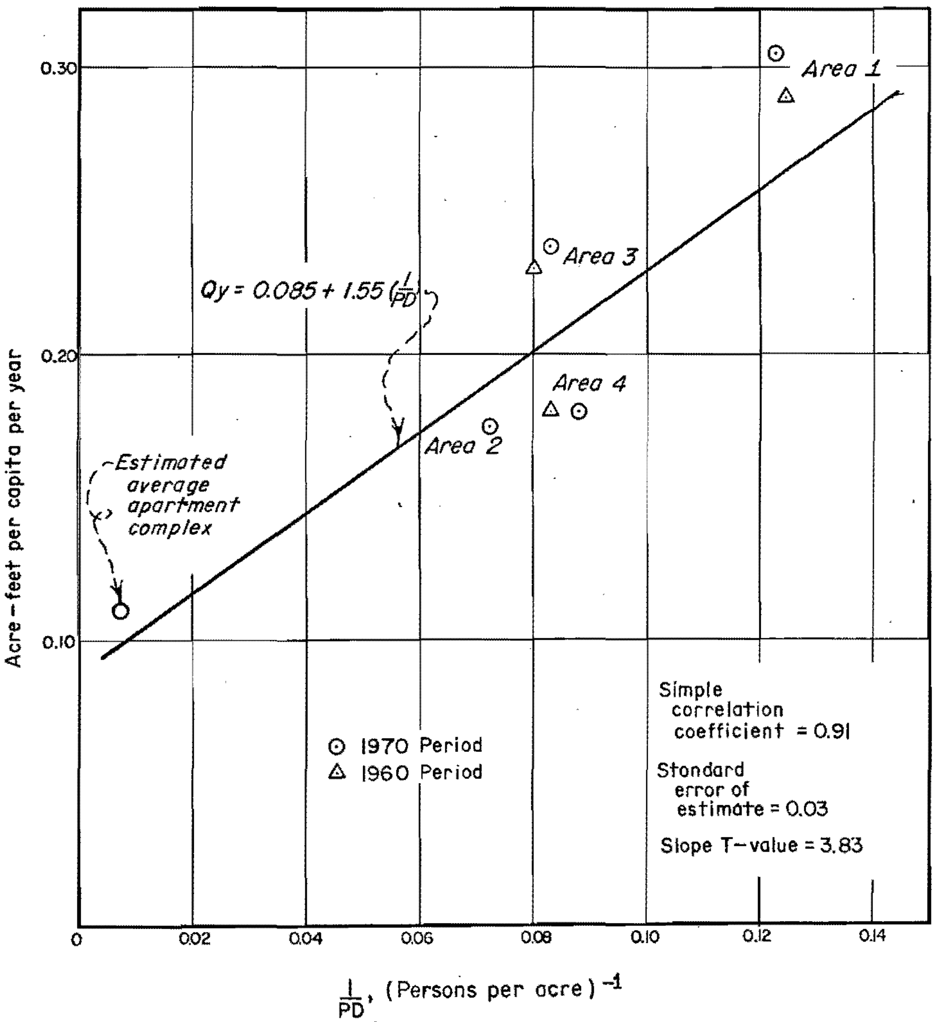


Figure 2. Qy vs. reciprocal population density, $\frac{1}{PD}$.

that such conversion will result in increased water use. However, a typical acre of agricultural land in the Salt Lake Valley annually requires approximately 0.8 acre-feet more water diverted per acre than the typical urban area; the typical agricultural acre requiring about 4.0 acre-feet and the average urban acre requiring about 3.2 acre-feet.

As pointed out above, the long term average per capita water use in Salt Lake County is 0.24 afpcy, or 214 gpcd. Because no significant trend could be established, the data were analyzed for extreme demands using the Log Pearson Type III probability distribution (which is commonly employed in hydrologic analyses). Based on the 1913 to 1969 data, extreme per capita water use values were predicted for Salt Lake County; these are shown in Table 3. A water use 25 percent larger than the mean can be expected to occur on the average about once every 100 years.

Also of interest are the annual recurring peaks of water use due to sprinkling in the spring and summer months. Approximately 40 percent of the total annual water delivery can be attributed to lawn sprinkling, most of which occurs in the period April through September. Based on the data for the two study periods (1959-1961 and 1969-1971), the average ratio of peak day to average daily flow is 2.34 and the 50-year recurrence interval extreme value of the ratio is 2.76.

Recommendations

1. During the second year of each future decade, several pilot areas should be selected (including those used in this investigation) and evaluated. The resultant correlation equations will be considerably more meaningful with several decades of analysis as well as with more pilot areas (which should include some additional high density housing).

2. The total municipal water use should be analyzed at least every 10 years to check the projections and values arrived at herein.

Table 3. Predicted extremal values of per capita water deliveries.

	Recurrence Interval (years)				
	2	10	25	50	100
	1913 to 1969 Data Base				
gpcd	214	240	250	257	263
$\frac{\text{ac-ft}}{\text{(cap)(yr)}}$	0.240	0.269	0.280	0.288	0.295
	1945 to 1969 Data Base				
gpcd	218	242	252	258	265
$\frac{\text{ac-ft}}{\text{(cap)(yr)}}$	0.244	0.271	0.282	0.289	0.297

3. Research should be instituted to determine the status of water intensive industries in the Salt Lake Valley, how they will develop, and a system of efficient management for matching the specific quantity of industrial water needs with alternative supply sources, especially as they relate to the phasing out of agricultural lands.

4. Future planning in Salt Lake County should bear strongly in mind the effects that population density has on per capita water use, especially as it relates to future zoning and projected socio-economic levels.

5. Municipal water planning should apply 0.24 acre-feet per capita per year (214 gpcd) to the future populations for average requirements and 0.30 acre-feet per capita per year (265 gpcd) for extreme year average, (100 year recurrence interval).

6. A program of public education be implemented to reduce the amount of wastage in lawn watering permitting the water supply of Salt Lake County to serve more people through more efficient use.

7. In selecting additional pilot areas for additional study, areas in and around Bountiful, Utah, should be selected, because the area has a dual water supply and a domestic water use could be accurately determined without interferences from the effects of sprinkler use.

WATER CHALLENGES IN CARBON AND EMERY COUNTIES*

by

Leland J. Myers, Rodney D. Millar,
and Richard E. Turley**

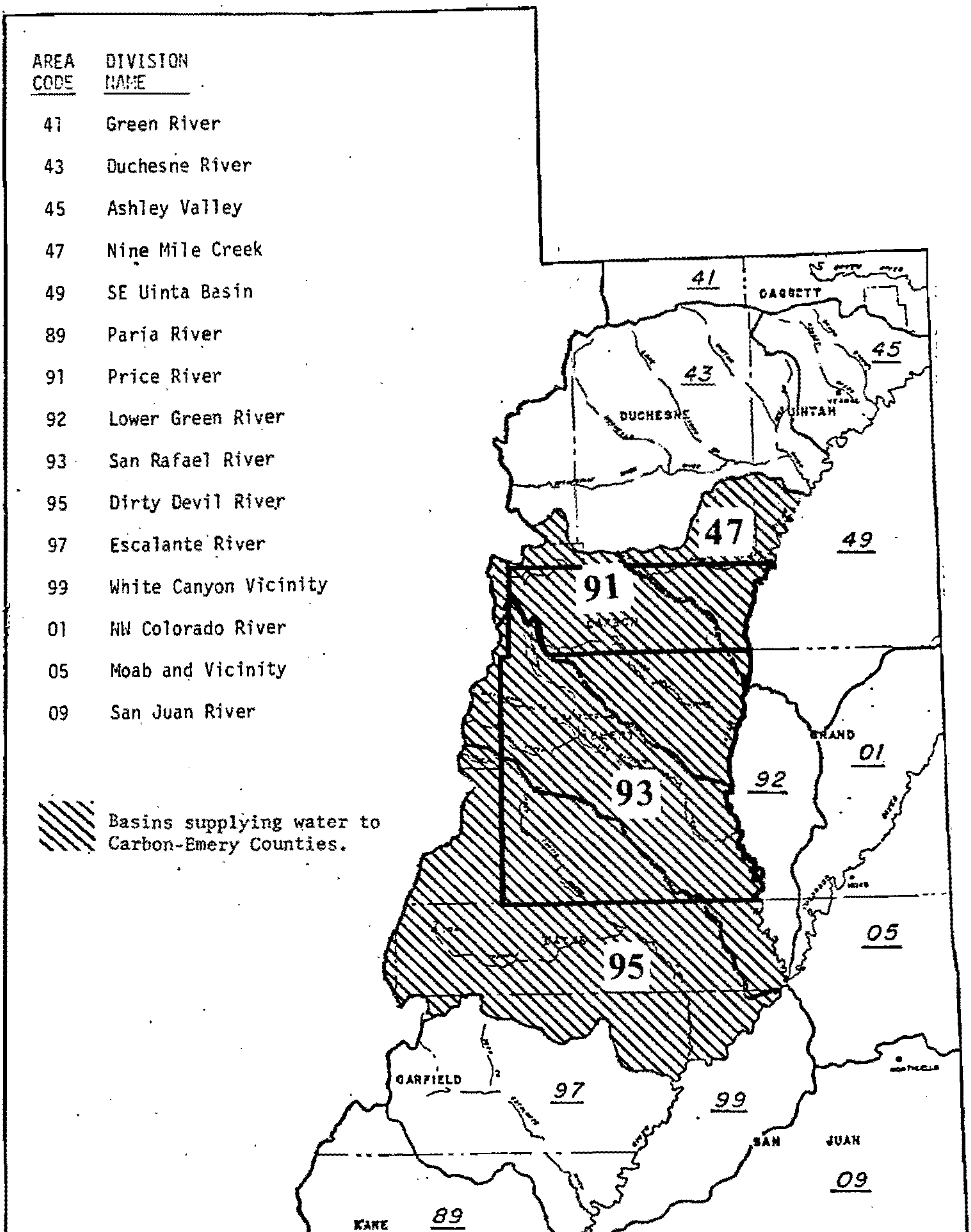
Water in Carbon and Emery counties is considered a scarce and valuable resource. Residents and industries within the area depend on seasonally fluctuating snow and rain fed streams for water. The more prominent streams in the Carbon-Emery area are Green River, Price River, Minnie Maud Creek, Nine Mile Creek, Huntington Creek, Cottonwood Creek, Ferron Creek, San Rafael River, and the Muddy Creek. These streams and other lesser streams and creeks make up the four hydrologic divisions having drainage into Carbon and Emery counties. These divisions are Nine Mile Creek Division, Price River Division, San Rafael River Division, and Dirty Devil River Division. These divisions are depicted in Figure 1 (1).

Water Quantity

The amount of water that flows in the rivers in the Carbon-Emery area is highly seasonal. There are many intermittant and ephemeral streams in the area which flow only during runoff periods. Runoff, of course, varies with the amount and type of precipitation. Other factors influencing runoff are topography, geology, soil, and vegetation. The combination of these factors results in seasonal variations which normally produce lowest flows during late summer and mid winter.

*Work performed through joint funding by the State of Utah and the Surface Environment and Mining Program (SEAM) of the U. S. Dept. of Agriculture, Forest Service.

**Office of the State Science Advisor, 3008 Merrill Engineering Bldg., University of Utah, Salt Lake City, Utah 84112.



Source: "Inventory of Water Rights Upper Colorado River Basin Utah," prepared by Div. of Water Rights, Utah, December 1974.

Figure 1. Hydrologic areas--Upper Colorado River Basin, Utah.

Normal annual precipitation varies widely in the Carbon-Emery area as shown in Figure 2 (2). This figure shows that most of the annual precipitation falls in the higher elevations.

Precipitation data are more meaningful when applied to mean annual streamflows in the area. Streamflow for the larger streams in the Carbon-Emery area are shown in Figure 3 (2, 3). This figure shows that the streamflow varies widely from point to point along a stream. This is because of water that is extracted and returned after use, and because of the addition of runoff. The average flow on the Price River above Price, Utah is 103,530 A. F. (Acre Feet) per year, and downstream the flow from the Price River into the Green River averages 70,590 A. F. per year. The flow in Huntington, Cottonwood, and Ferron Creeks averages 195,050 A. F. per year. However, the combined flow of these streams into the San Rafael River is only 89,050 A. F. per year. The flow of the San Rafael River into the Green River is 133,200 A. F. per year.

In order to provide water during periods of low runoff several water storage reservoirs have been constructed in Carbon and Emery Counties. These reservoirs are used to help regulate the flow in the streams to insure an adequate supply of water to various users during the year. These reservoirs are listed in Table 1 (4, 5, 6, 7). Several reservoirs located in Sanpete County are also included in Table 1. These provide water and recreation primarily to users in the Carbon-Emery area and therefore are considered resources of these counties. This table does not list every reservoir in the two counties, only the larger ones. All others are in the category of small stock watering ponds. Each reservoir listed in Table 1 has township, range and section coordinates given. The locations of these reservoirs have been plotted in Figure 4 and each one can be located using the coordinates given in Table 1.

Electric Lake Reservoir is of particular interest since it was constructed by Utah Power and Light Company to supply a continuous, steady amount of water to the recently finished Huntington Power Plant complex, the first large scale energy development in the region. This reservoir

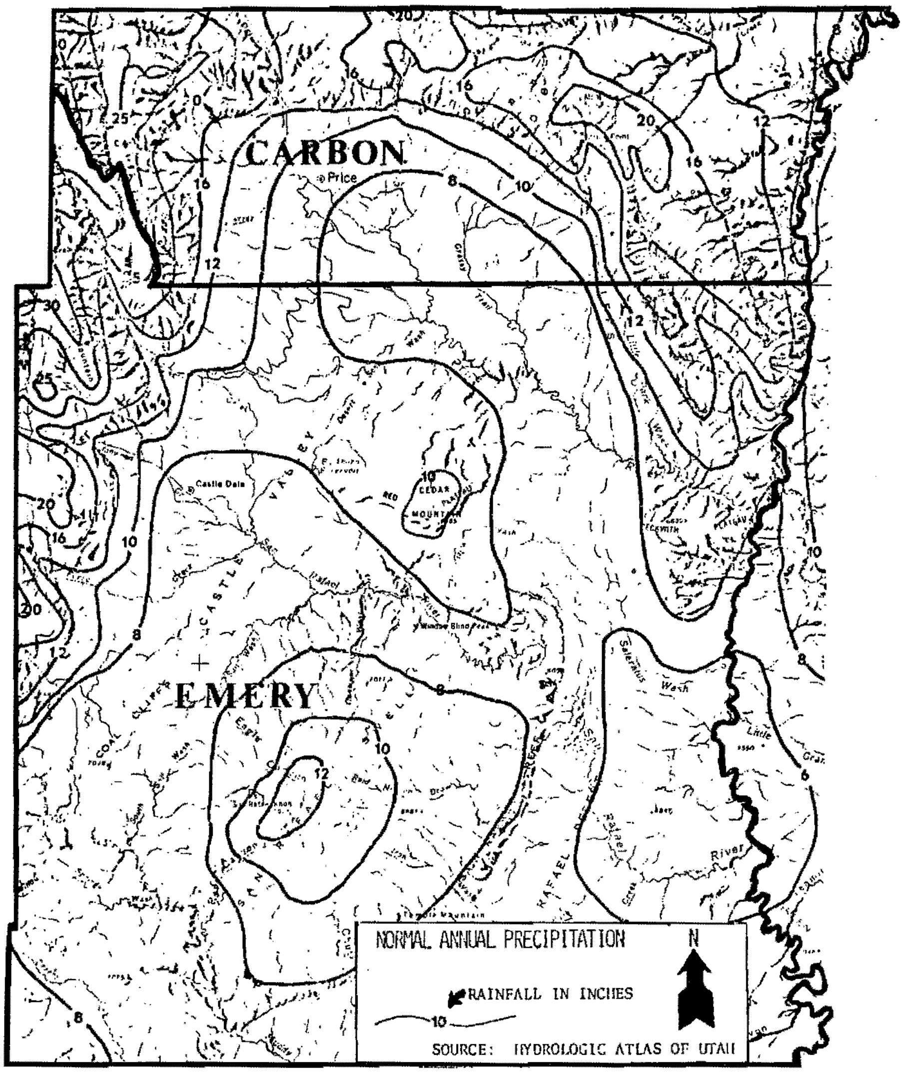
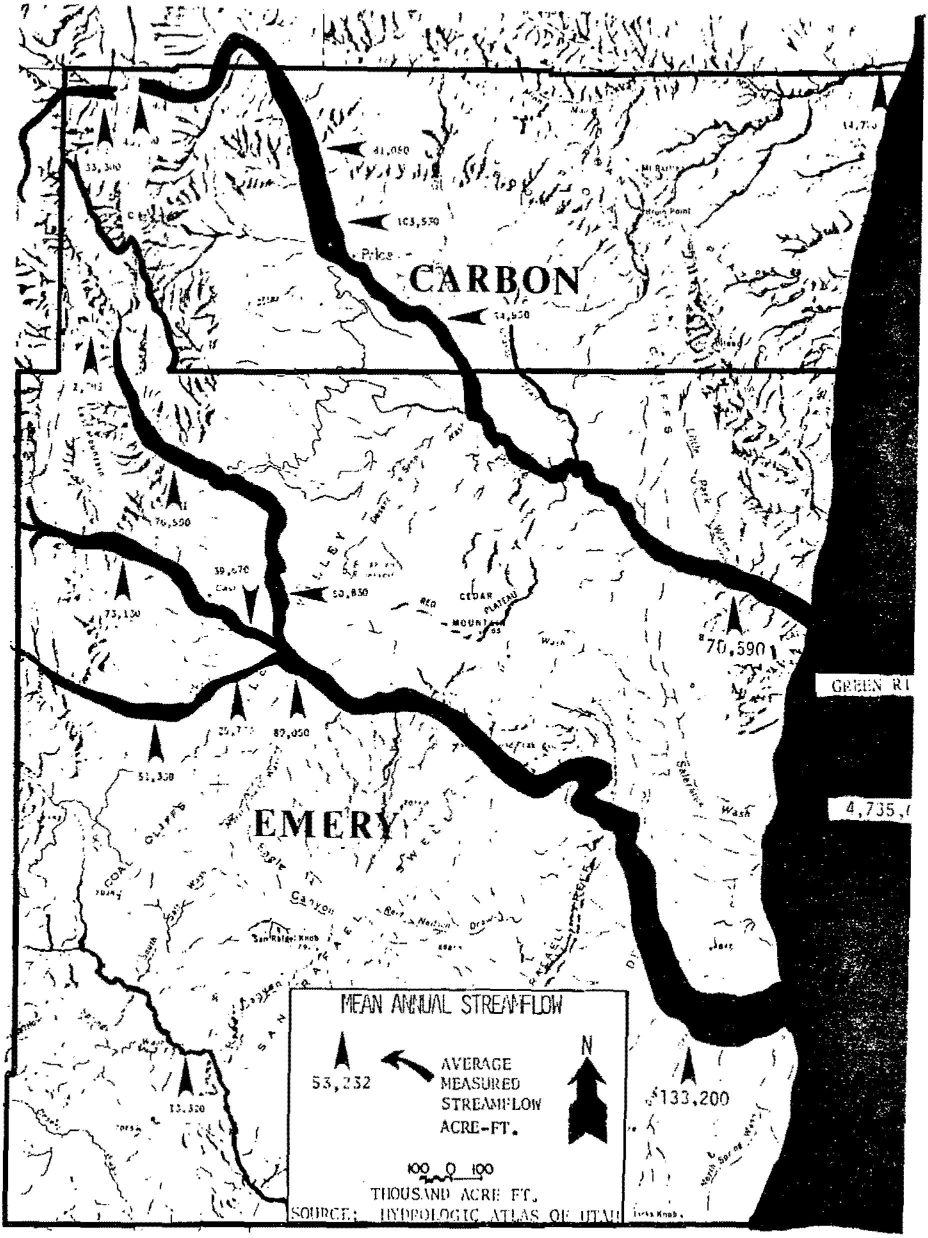

CARBON
Price
EMERY
Castle Dale
CEDAR MOUNTAIN
NORMAL ANNUAL PRECIPITATION
N
RAINFALL IN INCHES
10
SOURCE: HYDROLOGIC ATLAS OF UTAH

Figure 2.



CARBON
EMERY
Price
GREEN RI
4,735,
70,590
133,200
MEAN ANNUAL STREAMFLOW
53,232
AVERAGE
MEASURED
STREAMFLOW
ACRE-FT.
N
100 0 100
THOUSAND ACRE FT.
SOURCE: HYDROLOGIC ATLAS OF UTAH

Figure 3.

Table 1. Reservoirs in Carbon-Emery county area.*

Res. Name	County	Section	Township	Range	River or Stream
Anderson's Res.	Carbon	36	14S.	11E.	Soldier Ck.
Clarkes Valley Res.	"	10	14S.	12E.	Dugout Ck.
Grassy Trail	"	7	14S.	14E.	Grassy Trail Ck.
Miller Creek	"	30	15S.	9E.	Miller Ck.
Powell	"	6	12S.	12E.	Minnie Maud
Scofield	"	15	12S.	7E.	Price River
Buckhorn Dam	Emery	20	18S.	10E.	Buckhorn Wash
Cleveland	"	27	14S.	6E.	Spring Ck.
Desert Lake	"	3	17S.	10E.	----
Duck Fork	"	10	19S.	4E.	Duck Fork
Electric Lake	"	14	14S.	6E.	Huntington Ck.
Ferron	"	22	19S.	4E.	Indian Ck.
Huntington No.	"	17	17S.	9E.	Off Stream
Joe's Valley Res.	"	5	18S.	6E.	Cottonwood Ck.
Little Brush Ck.	"	14	20S.	4E.	Little Brush Ck.
Little Madsen	"	33	14S.	6E.	Rolfson Ck.
Millsite	"	12	20S.	6E.	Ferron Ck.
Red Pine 1	"	8	16S.	6E.	Lowry Fork
Red Pine 2	"	8	16S.	6E.	Lowry Fork
Willow Lake	"	29	19S.	5E.	Shingleton Ck.
Wrigley Springs	"	7	20S.	6E.	Slide Hollow
Academy Mill	Sanpete	5	18S.	5E.	----
Brush	"	4	20S.	4E.	No. Fork Muddy Ck.
Emery	"	4	20S.	4E.	No. Fork Muddy Ck.
Grassy Lake	"	26	17S.	5E.	Little Ck.
Henningson	"	20	20S.	4E.	Reservoir Ck.
Huntington	"	20	14S.	6E.	Spring Ck.
Miller Flat	"	3	15S.	6E.	Miller Flat Ck.
Pete's Hole	"	6	18S.	5E.	----
Rolfson	"	33	14S.	6E.	Rolfson Ck.
Soup Bowl	"	32	17S.	5E.	----
Spinner	"	2	20S.	4E.	No. Fork Muddy Ck.

Table 1. Continued.

Res. Name	Nearest City	Distance from Res.	Year Completed	Purpose	Structural Height
Anderson's Res.	Woodside	30	1936	I	32
Clarkes Valley Res.	Woodside	26	1917	I	14
Grassy Trail	Dragerton	7	1951	I,N,O	88
Miller Creek	Hiawatha	4	1931	I	30
Powell	Castle Gate	15	1940	I	22
Scofield	Scofield	10	1946	I,R,C,S	125
Buckhorn Dam	Cleveland	8	1968	I,C,O	35
Cleveland	Huntington	25	1908	I,R	40
Desert Lake	Elmo	2	----	O	--
Duck Fork	Ferron	18	1949	I,R	38
Electric Lake	Huntington	24	1973	H	204
Ferron	Ferron	23	1916	I,R	25
Huntington No.	Huntington	1	1965 E*	I	62
Joe's Valley Res.	Orangeville	12	1965	I,R,S,C	195
Little Brush Ck.	Moore	16	1903	I	36
Little Madsen	Huntington	24	1950	I	24
Millsite	Ferron	3	1971	I,S	122
Red Pine 1	Huntington	18	1908 E*	R	15.5
Red Pine 2	Huntington	18	1908 E*	R	17.5
Willow Lake	Ferron	15	1940	I,R	14
Wrigley Springs	Ferron	20	1956	I,R	23
Academy Mill	Orangeville	18	1908 E*	R	13.5
Brush	Moore	13	1926	I	30
Emery	Moore	18	1924	I	18
Grassy Lake	Orangeville	18	1945	R	22
Henningson	Moore	18	1947	I	6
Huntington	Huntington	23	1949	I	42
Miller Flat	Huntington	24	1953	I,R	75
Pete's Hole	Orangeville	19		R	16
Rolfson	Huntington	24	1929	I	36
Soup Bowl	Orangeville	19		R	13
Spinner	Moore	17	1926	I	15

Table 1. Continued.

Res. Name	Hydraulic Height	Max. Storage	Normal Storage	Owner	Remarks
derson's Res.	32 E.	229 E.*	229	H. Mahleres, S. Siampinos	
arkes Valley Res.	8	230 E.*	230	John Marakis	
assy Trail	84	1,003 E.*	1,003	Geneva - Kaiser Steel Co.	O - Industrial
ller Creek	26	174 E.*	174	Price River Irrigation Co.	Drains into Desert Lake
well	18	50 E.*	37	Sheridan R. Powell	Drains into Green River
ofield	55	73,600	65,800	Carbon Water Conservancy Dist.	
ckhorn Dam	28	8,799	2,753	Bureau of Land Management	O-Stock Watering; Drains into San Rafael
eveland	32	3,275 E.*	3,275	Huntington - Cleveland Irr. Co	
sert Lake	--	---	---	Forest Service	O - Waterfowl Reserve
ck Fork	32	718 E.*	718	Ferron Canal - Res. Co.	No Storage Allowed
ectric Lake	194	34,000	34,000 E.*	Utah Power & Light Co.	
rron	20	1,330	995	Ferron Canal - Res. Co.	
ntington No.	55	4,850	3,100	Bureau of Reclamation	
e's Valley Res.	--	71,600	54,630	Bureau of Reclamation	
ttle Brush Ck.	34	175 E.*	175	Independent Canal Res. Co.	
ttle Madsen	21	58 E.*	58	Huntington - Cleveland Irr.Co.	
llsite	100	18,000	18,000 E.*	Ferron Canal - Res. Co.	
d Pine 1	11.5	---	74	Forest Service	R - Fishing
d Pine 2	13.5	---	66	Forest Service	R - Fishing
llow Lake	14 E.	116 E.*	116	Ferron Canal - Res. Co.	
igley Springs	18	133 E.*	133	Ferron Canal - Res. Co.	
ademy Mill	9.5	---	46	Forest Service	R - Fishing
ush	30 E.	50 E.*	50	Muddy Creek Irr. Co.	
ery	18 E.	145 E.*	145	Muddy Creek Irr. Co.	
assy Lake	18	137	131	Forest Service	R - Fishing
nningson	6 E.	350 E.*	350	Muddy Creek Irr. Co.	
ntington	37	2,900	2,625	Huntington - Cleveland Irr.Co.	
ller Flat	70	5,561 E.*	5,561	Huntington - Cleveland Irr.Co.	
te's Hole	12	---	100	Forest Service	R - Fishing
lfson	30	900 E.*	900	Huntington - Cleveland Irr.Co.	
up Bowl	8.5	---	22	Forest Service	R - Fishing
inner	15 E.	550 E.*	550	Muddy Creek Irr. Co.	

Table 1. Continued.

RESERVOIRS IN CARBON-EMERY AREA *

(*) Reservoirs in Carbon and Emery Counties and those in Sanpete County which supply water or recreation for residents of Carbon and Emery Counties.

LEGEND

I - Irrigation	R - Recreation
H - Electric Power Production	S - Water Supply
C - Flood Control	O - Other
E*- Estimate	

Note: All Reservoirs in this table are of the Earth fill type.

SOURCE: Data compiled from Utah Division of Water Resources and U.S. Bureau of Reclamation records.

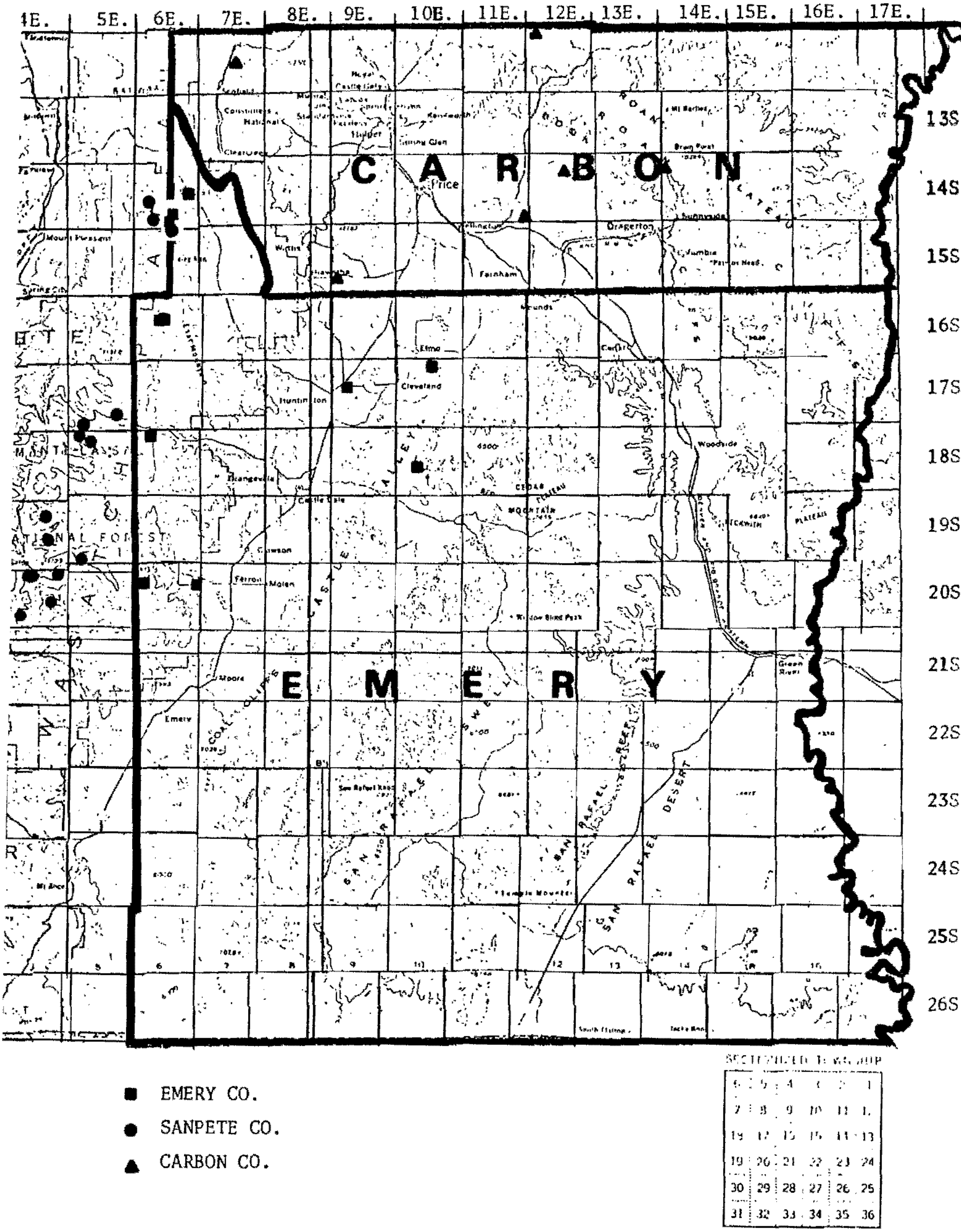


Figure 4. Reservoirs in the Carbon-Emery area.

represents a large scale water conservation project for the Carbon-Emery area.

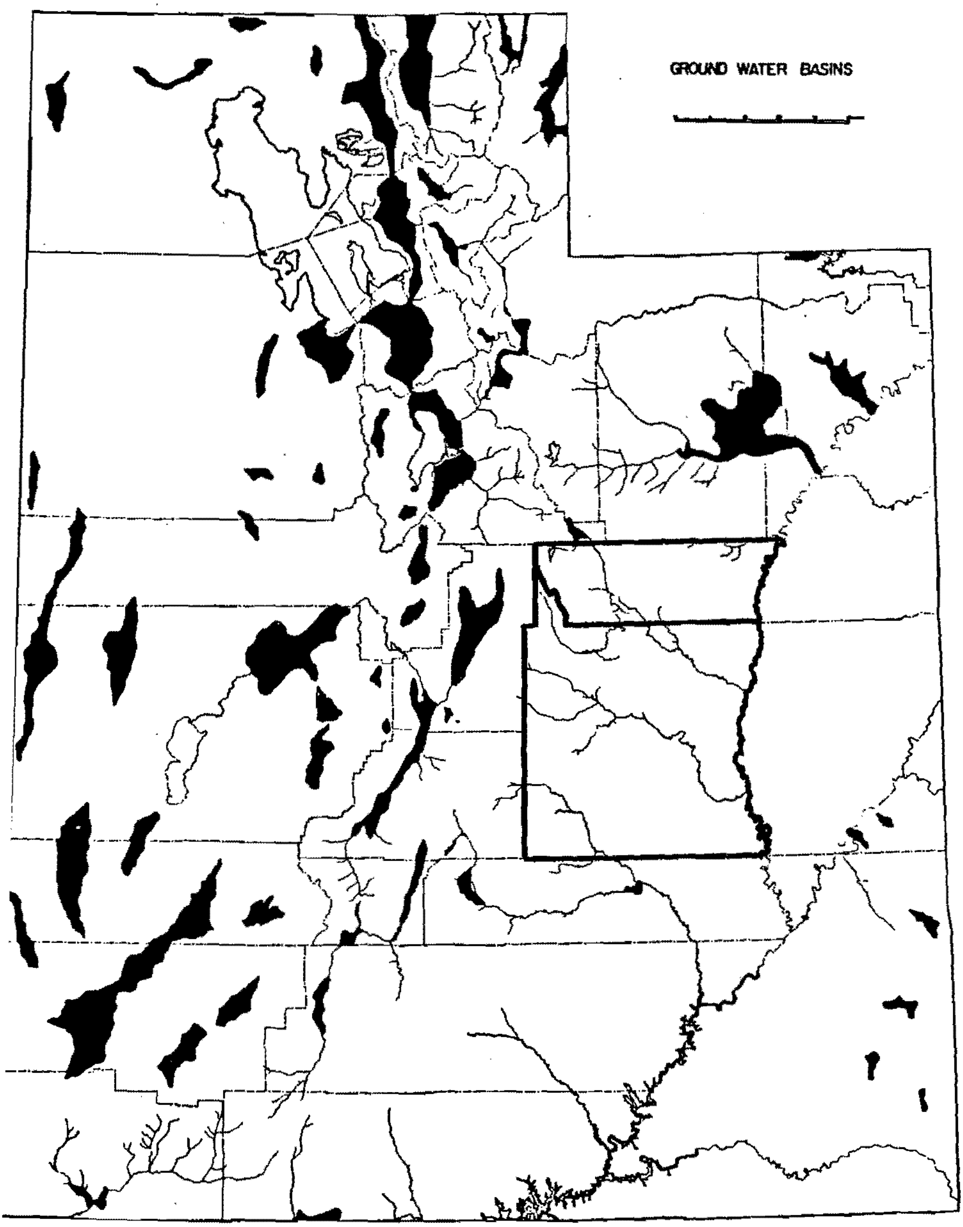
The Carbon-Emery area has no known or probable ground water reservoirs (2). This lack of ground water reservoirs severely limits the amount of water that can be extracted from the underground water table. Figure 5 shows the ground water resources in Utah. It is easily seen from this figure that the major ground water resources lie in the western half of the state and that Carbon and Emery counties are totally lacking in ground water resources. Many small towns in Carbon and Emery counties do however get at least a part of their culinary water from small wells, which result from the runoff water table.

Water rights

Currently there are nearly 1000 different allocated water users on the Price River (1). The uses of this water include stock watering, irrigation, coal mining, power generation, industrial, domestic, and many other smaller types of uses. The largest of these users are listed in Table 2.

At present there are no unappropriated water rights on the Price River, Cottonwood Creek, Huntington Creek, Ferron Creek, and the San Rafael River. The total average streamflow from these creeks and rivers has been allocated. This would mean that no water flowed into the Green River; however, there is a flow into the Green River which is caused by two factors. First, there is the agricultural return flow from flood irrigation. Second, it is evident that many water allocations are not being used.

We understand that Utah Power and Light Company has purchased water rights for the Huntington Generating Station and has sufficient water for future needs. For their North Emery Plant, U. P. & L. has leased water rights from farmers and others in the area on a 40 year lease. These water rights will therefore revert back to the control of the present owners after 40 years. Meanwhile the farmers in the area can still use the water as long as it is not needed for power generation.



SOURCE: "Hydrologic Atlas of Utah," Utah State University, Utah Division of Water Resources, Nov. 1968.

Figure 5.

Table 2. Selected water rights in Carbon-Emery counties.

River Div.	Source	Quantity C.F.S.	A.F.	Use	Applicant
ine Mile reek Division	Nine Mile Creek	5.0		I,S	T.A. Christensen
	"	10.7		I,S	C. Pace
	Cow Canyon Creek	4.0		I,S	A. Keel
	Minnie Maud Creek	10.0		I,S	Minnie Maud Irr. Co.
rice River ivision	Price River	125.0		I,S,D	Carbon Coal Co.
	"	56.3		I	Wellington Canal Co.
	"	50.0		I	Price River Water Users
	"	25.0		S,D	"
	"	32.4		I,S,D	Allred Ditch Co.
	"	37.0		I	"
	"	36.0		I	Spring Glen Canal Co.
	"	37.8		I	Pioneer Canal Co. #1
	"	32.4		I	Pioneer Canal Co. #2
	"	307.0		I,S	Carbon Canal Co.
	"	30.2		I,S,D	Price Water Co.
	Green River	220.0		P	Green River City
	"	35.0		I	Wilson Produce Corp.
	"	60.0		I,D,S	Green River Canal Co.
	"		50,000	S.G.	U.P. & L. Co.
	Fish Creek		17,980	I,In,Mu	Price River Water
				D,C,S	Users
	"		90,000	I	Bureau of Reclamation
an Rafael iver ivision	Ferron Creek	378.0		I,D,S	Board of Water Res.
	"		15,124	I,D,S,In	"
	Huntington Creek	75.0		I	Bureau of Reclamation
	"	75.0	15,043	I	H.-C. I.C.
	"		60,000	S.G.	U.P. & L. Co.
	Lowry Fork	100.0	20,000	I	Bureau of Reclamation
	Cottonwood Creek	122.82		I	C.C.C.I.C.
	"		117,546	I	Bureau of Reclamation
	Green River	40.0		D,S.G.	Western Development Co.
	S. Straight Hollow	25.0	500	I	Ferron Canal & Res. Co.
	Olsen Canyon	23.0		I,S	Horseshoe Canal Co.
irty Devil iver ivision	Muddy Creek	50.0		I,S	Muddy Creek Irr. Co.
	"	100.0		I	C.C. Moore
	UGW	20.0		Misc.	Kemmerer Coal Co.

1 C.F.S = 722.7 A.F.

C.F.S. - Cubic Feet Per Second
A.F. - Acre Feet Per Year
I - Irrigation
In - Industrial
D - Domestic
C.C.C.I.C. - Cottonwood Creek Con. Irr. Co.

Mu - Municipal
S.G. - Steam Generation
P - Power Hydro
S - Stock Watering
Misc. - Miscellaneous
UGW - Underground Water Cl
H-C.I.C. - Huntington-Clevel Irr. Co.

SOURCE: "Inventory of Water Rights, Upper Colorado River Basin, Utah," Prepared by Div. of Water Rights, Salt Lake City, Utah Dec. 1974.

This arrangement is very satisfactory for the persons concerned and presents no conflict between industry and agriculture (8).

Water quality

An analysis of water quality can be divided into two major areas. The first area is chemical pollutants and its associated water quality problems, and the second area is biological pollution and its problems. Before each of these areas is analyzed, several general comments are in order. Streamflow vs. pollution is generally an inverse relationship. As streamflow increases the dillution of the pollutants also increases. This would indicate that during periods of high flow the pollution concentration will decrease and conversely that at low flow the pollution concentration will increase. For this reason, low flow conditions are critical in evaluating water pollution and the effect that future developments will have on water quality.

The state of Utah has established minimum water quality standards that must be met in order for water to fit into several classes. These classes are:

Class "A" Waters - Domestic water supply without treatment.
Class "B" Waters - Domestic water supply after disinfection.
Class "C" Waters - Domestic water supply after coagulation, sedimentation, filtration, and disinfection.
Class "D" Waters - Limited irrigation uses.
Class "E" Waters - Those not already listed.

The standards for each of these classes of water are listed in Table 3 below (9). This list does not include all the various standards that should be met. However, these parameters provide a measure of the present water quality. These standards deal with controllable pollution and do not govern natural pollutants. All unlabeled numbers are mg/liter.

Table 3. Water quality standards.

Quality Factor	Class A	Class B	Class C	Class D
COLIFORM	1 MPN	50 MPN	5000 MPN	5000 MPN
PH	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5
BOD	NONE	NONE	< 5	< 25
IRON	0.3	0.3	0.3	0.3
MAGNESIUM	0.5	0.05	0.05	0.05
NITRATE	45	45	45	45
SULFATE	250	250	250	250
TDS	500	500	500	500

Chemical

Chemical pollution in the Carbon-Emery area water varies from very little at the head waters of the streams to excessive at their mouths. One indicator of this chemical deteoriation is the acceptable level of total dissolved solids (TDS) for irrigation water. Water which will have no detrimental effects upon the crops will have a TDS less than 500 mg. per liter. Sensitive crops can be affected by TDS levels between 500 and 1000 mg. per liter. Between 1000 and 2000 mg. per liter an adverse effect may be noticed unless careful water management is practiced. For a TDS level greater than 2000 mg. per liter only certain tolerant plants can be cultivated and then only under a careful management program (10). In the Price River the TDS level just below Scofield Reservoir is 211 mg/liter. As the water from the Price River enters the Green River the TDS concentration is 3154 mg/liter. Similarly the San Rafael River complex has the same TDS pattern. At the headwaters of the Huntington, Cottonwood, and Ferron Creeks the TDS concentrations are 202 mg/liter, 929 mg/liter, and 661 mg/liter respectively. Close to where the San Rafael meets the Green River a TDS concentration of 2125 mg/liter has been observed (11, 12, 13).

A second parameter of chemical pollution is water hardness. Hardness of water is produced by the presence of alkaline earths such as calcium and magnesium. A concentration of 0-60 mg/liter is considered soft, and from 61-120 moderately hard, and 121-180 hard, and from 180 on is considered very hard (10). All of the streams in the Carbon-Emery area recorded hard to very hard water. Concentrations ranged from 168 to 1674 mg/liter (12, 13).

Figure 6 is a graphical representation of TDS concentrations and it also shows other chemical parameters collected at various stations. These data were collected during 1973 and 1974 under the direction of the Utah State Division of Health. Four samples were taken and evaluated at the various stations. The samples were averaged and the numbers found are displayed in Figure 6 (12, 13). It is recognized that these numbers may not be accurate at all times since a wide variation often existed between samples. However, for a general overview and for purposes of comparison this data can be considered adequate.

Biological

The most common parameter used in biological evaluation of a water source is coliform count. Coliform count refers to the fecal coliform bacteria which flourish in the guts and feces of warm-blooded animals, including man. Escherichia coli is the organism used as an indicator of fecal origin. The coliform bacteria apparently do not themselves cause disease, but their presence in water suggests that disease-causing organisms (pathogens) may also be present. It is not feasible to identify the exact concentration of coliform bacteria in a water sample. Therefore, a quantity called the most probable number (MPN) is used to interpret test results in terms of results observed. It is reported as MPN per 100 milliliters of sample (MPN/100ml) or simply MPN values. For the Carbon-Emery area the coliform levels range from less than

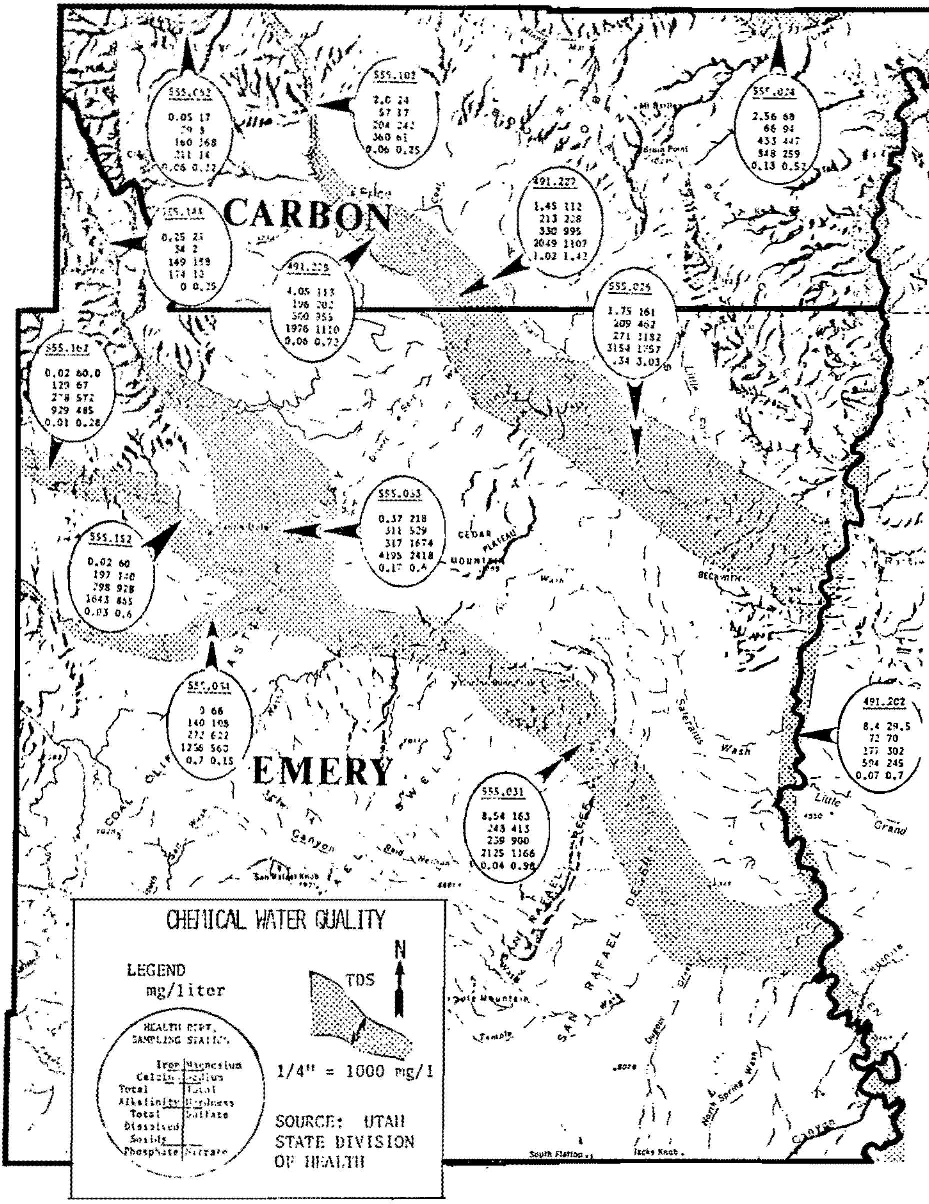

CARBON
EMERY
555.102
491.227
555.025
555.033
555.152
555.031
491.202
555.162
CEDAR MOUNTAIN
CHEMICAL WATER QUALITY
LEGEND
mg/liter
TDS
N
1/4" = 1000 mg/l
SOURCE: UTAH STATE DIVISION OF HEALTH
Iron
Magnesium
Total Alkalinity
Total Dissolved Solids
Phosphate
Nitrate

Figure 6.

3 MPN to more than 230,000 MPN for individual samples. Coliform deterioration is most probably a result of sanitary sewage being discharged into the streams and rivers.

The next parameter considered is biochemical oxygen demand (BOD). This is a measure of the living and nonliving organic demand for oxygen imposed by wastes of various kinds. A high BOD may temporarily, or permanently, so deplete oxygen in the water as to kill aquatic life. The determination of BOD is perhaps most useful in evaluating impact of wastewater on the receiving water bodies (15). Excessive BOD values have been observed along both the Price River and San Rafael River complex. Table 3 gives values of zero for Class A and B water and less than 5 for Class C waters and less than 25 for Class D waters as minimum standards for BOD. Values as high as 750 BOD were recorded at the Carbon-Emery-By-Products' plant discharge into Drunkard's Wash below Price, Utah (13). Although most streams in the Carbon-Emery area show values much less than this there are several areas which exceed Class D water standards.

Another parameter, not included in Table 3 is the Dissolved Oxygen (DO) content of water. Nonliving organic matter and various chemicals react with oxygen in water, depleting the oxygen and causing stress from lack of oxygen on fish and other aquatic life. In extreme depletion, water may become anaerobic and stagnate, and as a result stink. Thus the ability of a stream to assimilate organic wastewater discharges is dependent on the concentration of available DO. In the Carbon-Emery area DO levels should exceed 5.5 mg/l. DO values recorded in the Carbon-Emery area vary from about 8 to 16.

The last parameter we will consider here is PH. This is a measure of the hydrogen-ion activity in solution. It is expressed on a scale of 0 (highly acid) to 14 (highly basic). A PH of 7.0 is a neutral solution, neither acid or basic. Biological systems normally do not vary much from neutral. Table 3 gives a range of 6.5 to 9.0 for water standards. Most PH values in the Carbōn-Emery area are between 8 and 9.

Figure 7 displays the various biological parameters discussed with representative values. The points refer to the stations mentioned for Figure 6.

Present water uses

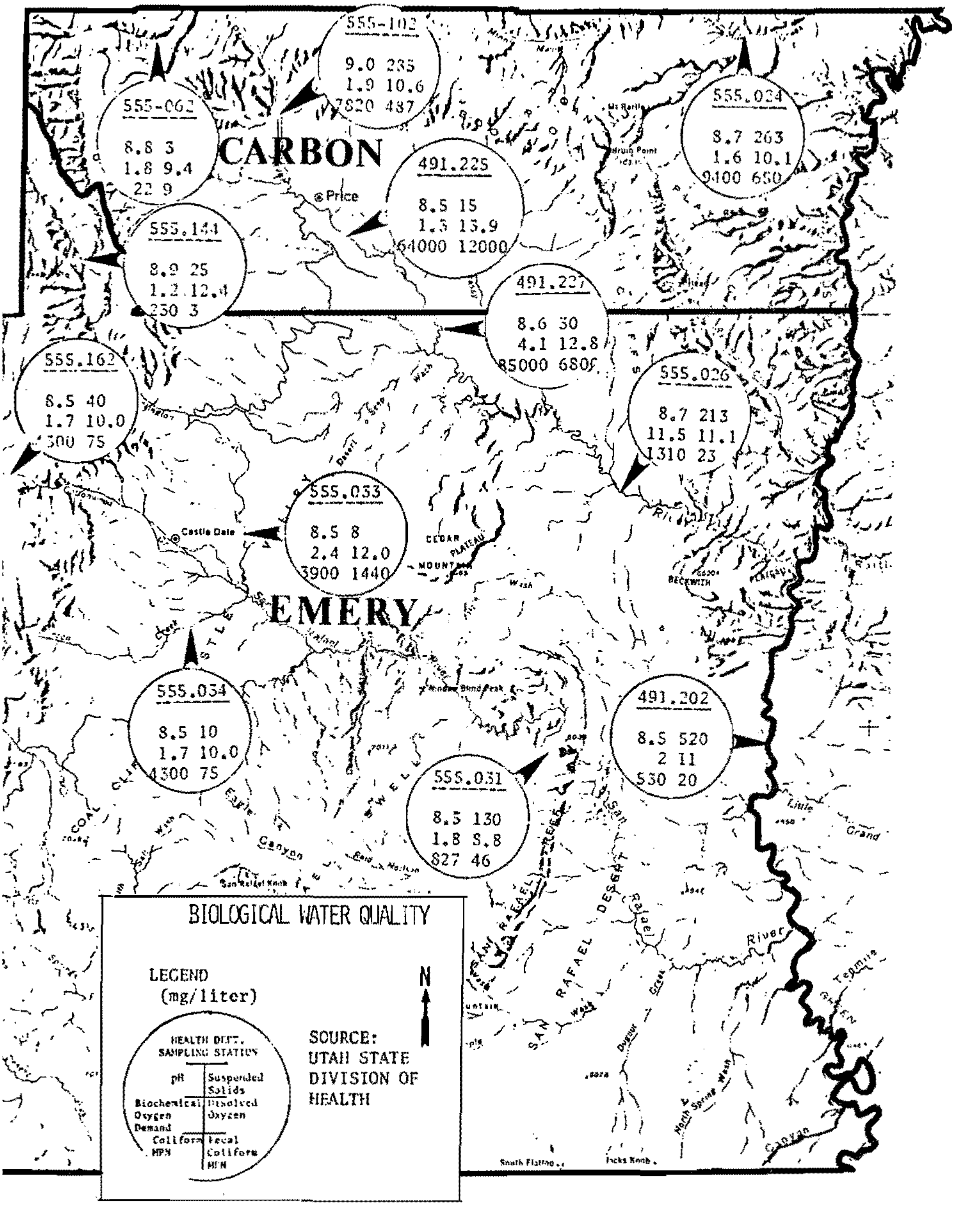
The uses of water in the Carbon-Emery area are pretty much the same as anywhere else. These consist of agriculture, industry, culinary, recreation and other uses which determine the standard of living of a community. These uses will be discussed more fully relative to the situation in Carbon and Emery counties.

Agriculture. Water use for agriculture in the Carbon-Emery area is not as large as many other areas of Utah. In Carbon County there are 12,344 acres of irrigated cropland which amounts to 1.3 percent of the total land area (16). Emery County has 38,604 acres of irrigated cropland or 1.4 percent of the total land mass for this county. The primary crops grown in the study area are wheat, hay, alfalfa, corn, oats, barley, sugarbeets, and potatoes. Table 4 shows the percentages, of the state total, that these crops represent. It is evident from this table that the agricultural effort in these two counties, with the possible exception of corn and oats, is not large in comparison with the total state effort. Fruit production in the study area is even less significant compared to the state totals.

Table 4. Carbon-Emery crop production - percentage of state total.

	Wheat	Hay	Alfalfa	Corn	Oats	Barley	Sugarbeets	Potatoes
Carbon	.4	.95	1.0	.14	3.7	.19	4.8	.24
Emery	1.3	2.8	2.9	5.5	11.2	.45	---	.01
Total	1.7	3.75	3.9	5.64	14.9	.64	4.8	.25

SOURCE: "Utah Agricultural Statistics - 1974."



555-102
9.0 235
1.9 10.6
7820 487
555-062
8.8 3
1.8 9.4
22 9
CARBON
Price
491.225
8.5 15
1.3 13.9
64000 12000
555.024
8.7 263
1.6 10.1
9400 650
555.144
8.9 25
1.2 12.4
230 3
491.227
8.6 30
4.1 12.8
555.162
8.5 40
1.7 10.0
555.026
8.7 213
11.5 11.1
1310 23
555.033
8.5 8
2.4 12.0
3900 1440
Castle Dale
EMERY
555.034
8.5 10
1.7 10.0
4300 75
491.202
8.5 520
2 11
530 20
555.031
8.5 130
827 46
BIOLOGICAL WATER QUALITY
LEGEND
(mg/liter)
HEALTH DEPT. SAMPLING STATION
pH
Suspended Solids
Biochemical Oxygen Demand
Dissolved Oxygen
Coliform MPN
Fecal Coliform MPN
N
SOURCE:
UTAH STATE
DIVISION OF
HEALTH

Figure 7.

Industry. The industries in the study area that have significant consumptive uses of water are mostly energy related. The largest users are the power companies. Utah Power and Light Company (UP&L) presently diverts water for use in cooling at the Castle Gate and Huntington plants. They have purchased and/or leased water rights for the present and future Huntington generating plant and for the future North Emery generating plant. In Emery County U. P. & L. has acquired water rights through 40 year leases. These water rights were formerly used for irrigation.

Culinary. Municipal water systems in the study area are barely adequate for the present population. Table 5 gives data on the culinary water supplies of the two county area (17). Carbon County is better off than Emery County but even so five of their systems are listed as "Not Approved" by the State Division of Health. Emery County has two systems listed as "Not Approved," however, Emery has only one system "Provisionally Approved" while Carbon has eight. Neither county has any "Approved" systems at this time.

Recreation. The recreational uses of water in the study area are mainly boating, fishing, and swimming. Recreational boating is pretty much confined to the larger reservoirs, principally the Scofield Reservoir. River running by raft and kayaks, with the exception of the Green River, represents a small percentage of recreational use in the Carbon-Emery area because of the small size of streams there. Fishing is enjoyed in many streams and reservoirs in the study area. Scofield Reservoir is a favorite spot for many fishermen as is Huntington Lake and Millsite Reservoir. The Forest Service has rejuvenated six reservoirs in the Emery-Sanpete border area, which were formerly irrigation reservoirs, to be used for recreational fishing only. These are Red Pine 1, Red Pine 2, Academy Mill, Grassy Lake, Pete's Hole and Soup Bowl reservoirs. In addition, Desert Lake is a waterfowl reserve.

Wastewater treatment. The wastewater treatment facilities for both domestic and industrial purposes are shown in Table 6 and 7. The data in Table 6 indicate, that with the exceptions of the Price City area

Table 5. Culinary water supply ratings in Carbon-Emery counties (as of January 1975).

System	Ownership	POPULATION SERVED Approved	Provisionally Approved	Class Pending	Not Approved	Date Assigned	Number of Connections	Ave. use gal. per conn. per day 3
CARBON CO.								
Aspen View (subdivision)	Private				50	12-6-74		
Carbonville	Private			100			49	
Clear Creek	Private		85				45	
East Carbon City 1	Public				1905			700
Helper	Public		2200				760	800
Hiawatha	Private		175				75	
Kenilworth	Private		425				103	
Price 2	Public		7000				2306	600
Scofield	Public		100				60	
Scofield Mt. Home (subdiv.)	Private				50	12-6-74		
So. Price Water Co.	Private				100		111	
Spring Glen	Private		545				190	
Sunnyside	Private				500			
Wellington	Public		1050				497	
County	Total							
Total	14,285		11,580	100	2605			
No. Systems	14		8	1	5			

Table 5. Continued.

System	Ownership	POPULATION SERVED Approved	Provisionally Approved	Class Pending	Not Approved	Date Assigned	Number of Connections	Ave. use gal. per conn. per day ④
EMERY CO.								
Castle Dale	Public			617		11-27-73	175	5-600
Clawson	Private				80		25	
Emery	Public			345			75	557
Ferron	Public		700				250	
Green River	Public			1275			365	
Huntington	Public				890	8-15-73	45	500
N. Emery Water Users ③	Public			1000				800
Orangeville	Public			550			180	
County	Total							
Total	5457		700	3787	970			
No. Systems	8		1	5	2			

① Previously Columbia & Dragerton.
② Price City system serves Wellington, Old Highway Water Co., So. Price Water Co., Westside Water Users, Carbonville Water Co., Haycock Land Water Co., Spring Glen Water Co., Emery Star Route Water Co., East Carbonville Water Co., Kenilworth Water Co., and 200 individual homes.
③ Serves Cleveland, Elmo, and Lawrence.
④ Division of Environmental Health estimates.

SOURCE: "Public Water System Ratings," County Listings, January 1, 1975, Bureau of Water Quality, State of Utah, Dept. of Social Services, Division of Health, Pp. 4,8.

Table 6. Domestic wastewater facilities in Carbon-Emery counties.

SYSTEM	Est. Pop. Served	DATE BEGAN Sewer System / Treatment Plant	Ave. Daily Flow MGD	DESIGNED FOR Mean Flow MGD / P.E. (1000's)	TREATMENT FACILITIES
CARBON COUNTY 1	2	3	4	5	6
Clear Creek	35	1941/---	0.003 E.	-- / --	CS
E. Carbon City					
Columbia	235	1940/1940	0.024 E.	0.075/0.75	CI
Dragerton	1,614	1940/1942	0.21 E.	0.45/2.7	*SH-(CM-DM)-FT2H-EG-BO
Helper	2,439*	1922/---	0.27	---/---	CS
Hiawatha	170	1929/ND	0.017	---/---	CS-POND *
Kenilworth	464	ND/---	0.05 E.	---/---	CS
Price	7,770	1910/---	0.83	---/---	--
Price River WID	12,121*	1971/1971	1.3	1.8/24.1	GH-SC-CM-FT2H-CM-EG-DFHMR-BOAU
Spring Glen	624	1971/---	0.052 E.	---/---	--
Sunnyside	600	1940/1953	0.06 E.	0.3/3.0	AP-GW-CI-FT1H-CM BOS-FS-ECG
Wellington	1084	1951/---	0.091	---/---	--
EMERY COUNTY					
Castle Dale	661	1928/---	0.07	---/---	NONE
Green River	1700	1936/1965	0.17	0.16/1.6	SC-GH-CM-FT1H-EG CM-DCMR-BOAU
Huntington	1325	1937/1960	0.13	---/---	LO*
Ferron	800	1939/1974	0.1	0.1/0.96	LO
Orangeville	600	ND/---	0.06 E.	---/---	NONE*

Table 6. Continued.

SYSTEM	DOWNSTREAM USE/ Pollution Abatement Needs	DISCHARGED TO	P.E. (BOD) Untreat. Waste / Dischgd. Waste	REMARKS
	7	8	9	10
CARBON COUNTY				
Clear Creek	ABCDFHJ/0	Clear Creek	31/31	Septic tanks and drain fields.
E. Carbon City				
Columbia	CD/0	Dry ditch to Price River	235/235	Inadequate
Dragerton	CD/2	Irrigation	1614/833	*No secondary settling or Chlorine contact facilities
Helper	BCD/7	Price River WID	--/--	*See App.
Hiawatha	BCD/0	Miller Creek to Price River*	170/59 E.	*Major portion of waste water flow dischgd. to slurry ponds
Kenilworth	BCD/0	Price River	464 E./464 E.	----
Price	CD/0	Price River WID*	--/--	*See App.
Price River WID	CH/7	Price River	12121/1721	*See App. cannot meet 1977 standards.
Spring Glen	--/--	Price River WID*		*See App.
Sunnyside	-/7	Whitmore Canyon	600/38	
Wellington	--/--	Price River WID*		
EMERY COUNTY				
Castle Dale	CD/0	Cottonwood Creek	661/661	Only a collection system
Green River	CDFHJ/7	Green River	1700/320	Generally satisfactory, but cannot meet 1977 standards
Huntington	CE/0	Lagoon eff. to Irr. ditch Raw W.W. dischgd. to H.C.	1417**/1417	*New lagoon built, not in use **Includes 92 P.E. ind. waste
Ferron	CD/7	NONE	930*/0	Lagoons and collection systems under construction * Includes 130 P.E. slaughter house wastes.
Orangeville	CD/0	Cottonwood Creek	600/600	*Applied for grant to construct facilities 1974 presently, raw sewage is dischgd. to Cottonwood Ck

Table 6. Continued.

*App. Price River Water Improvement District - Treatment Plant

Municipalities	No. Connections	Est. Pop. Served	Est. Flow MGD
Castle Gate } Helper	864	2,643	0.287
Price	2,590	7,770	0.83
Wellington	271	1,084	0.091
Spring Glen & Unicorp. Areas	156	624	0.052
TOTALS	3,881	12,121	1.27

NOTES:

BOD - Biochemical Oxygen Demand
ND - Data Not Available
WID - Water Improvement District
E. - Estimate
P.E. - Population Equivalent, in thousands, as measured by BOD, for which the treatment facilities were designed.
MGD - Million Gallons Per Day

KEY TO SYMBOLS - COLUMN 6

AP - Aeration, plain, without sludge return.
BO - Open sludge beds.
BOAU - Sludge beds, open, asphalt surfaced, underdrains provided.
BOS - Open sludge beds, sand surfaced.
CI - Two story Imhoff settling tanks.
CM - Mechanically equipped settling tanks.
CS - Septic tanks .
DCMR - Digester, separate sludge, with fixed cover, stirring mechanism, heated.
DFHMR - Digester, separate sludge, with floating cover, gas used in heating, stirring mechanism, heated.
DM - Digester, separate sludge with stirring mechanism.
ECG - Chlorination with contact tank by chlorine gas.
EG - Chlorination by chlorine gas.
FS - Intermittent sand filters.
FT1H - High capacity, single stage filters.
FT2H - High capacity, two stage filters.
GH - Grit chambers without continuous removal mechanism.
GW - Grit chambers, separate grit.
LO - Oxidation lagoons or ponds.
SC - Screens, comminutor (screenings ground in sewage stream)
SH - Screens, bar rack (1/2" to 2" openings) hand cleaned.

KEY TO SYMBOLS - COLUMN 7

TOP LINE ENTRY - Existing water uses downstream from the point of waste discharge.
A - Source of domestic water supply.
B - Source of industrial water supply.
C - Livestock water supply.
D - Irrigation water supply.
E - Commercial fishing.
F - Game fishing.
H - Wildlife.
J - Other recreation.

KEY TO SYMBOLS - COLUMN 7

BOTTOM LINE ENTRY - Needs of a facility according to the Utah Water Pollution Control Board standards.
0 - New treatment facilities needed.
2 - Addition of other treatment methods to existing facilities needed.
7 - No project needed.

SOURCE: Adapted from; "Domestic Wastewater Facilities in Utah," 1975 update to 1971 inventory. State of Utah, Dept. of Social Services, Division of Health, S.L.C., Utah.

Table 7. Industrial wastewater facilities in Carbon-Emery counties.

LINE NO.	INDUSTRY	TYPE OF INDUSTRY	LOCATION	ESTIMATED BOD PRODUCED LBS/OPERATING Day Sanitary/Process	Month Sanitary/Process	Year Sanitary/Process	WASTE TREATMENT FACILITIES Sanitary	Process
	CARBON COUNTY 1	2	3	4	5	6	7	8
1	Carbon-Emery By-Products	Animal By-Products	Price	1/10	19/14,351	220/166,430	CS-IS	CS-IS
2	Jeanselmes Mkt. & Slaughter House	Slaughter House	Price	1/143	7/1,859	80/22,310	NONE	NONE
3	Mariani Air Products	Misc. Dry Ice	Wellington	1/7	11/152	100/1,460	CS	KC-P
4	North American Coal Corp.	Misc. H20 Treat	Castle Gate	0/0	3/0	40/0	NONE	NONE
5	Plateau Mining Co.	Mining Coal	Price	6/0	180/0	2,190/0	CS-IS	LE-Recycle
6	U.S. Fuel Co.	Coal Washing	Hiawatha	16/0	356/0	4,260/0	CS	LP
7	Utah Power & Light Co.	Misc. Elect. Power	Castle Gate	5/57	150/1,710	1,830/20,810	CS-IS	P
8	Wellington Coal Cleaning Plant	Coal Washing	Wellington	4/0	69/0	840/0	CS-IS	LPE
	EMERY COUNTY							
9	Justice Meat Co. a	Slaughter House	Huntington	0/393	9/477	100/5,720	CS-IS	NONE
10	Kilpack Locker Plant	Slaughter House	Ferron	0/245	2/518	30/6,240	NONE	NONE
11	Miller & Curtis Packing Co.	Slaughter House	Castle Dale	0/48	10/1,248	120/14,980	NONE	NONE
12	Peabody Coal Co.	Mining Coal	Huntington	8/0	228/0	2,740/0	KC	LP

Table 7. Continued.

LINE NO.	ESTIMATED BOD DISCHARGES LBS/OPERATING			WASTE WATER DISCHARGE					REMARKS
	Day	Month	Year			VOLUME GALS./OPERATING		DOWNSTREAM USE/	
						Day	Month	Pollution Abatement Needs	
	Sanitary/Process	Sanitary/Process	Sanitary/Process	To Sanitary	To Process	Sanitary/Process	Sanitary/Process		
	9	10	11	12	13	14	15	16	
1	1/0	17/14,351	190/166,450	Price River Underground	Price River Underground	140/1,000	3,330/23,800	BCDH/O	Cannot Meet 1977 Standards
2	0/143	0/1,859	0/22,310	Price RWID Sewer	Price RWID Sewer	20/4,900	260/63,700	CD/7	
3	0/7	2/152	20/1,460	Price River	Price River	180/77,000	3,910/1,670,900	BCDH/X	Reviewed from COE Appln. 7-6-71
4	0/0	3/0	40/0	None	Price River	0/80,000	0/2,400,000	CDH/O	COE Appln. 7-15-71
5	0/0	0/0	0/0	Underground	Pond	600/1,000	18,000/30,000	-/7	
6	0/0	0/0	0/0	Miller Ck.	Pond	16,300/70,700	353,[illegible]20/1,534,190	CD/O	Reviewed 10-27-67
7	0/57	0/1,710	0/20,810	---	Price River	500/140,000	15,000/4,200,00	DFHI/2	
8	0/0	0/0	0/0	Underground	Pond&Recirc.	800/316,000	13,840/5,480,640	-/7	Reviewed 10-26-67
9	0/393	0/477	0/5,720	Underground	Huntington Ck. & Irr.	40/3,100	870/108,000	DFH/O	Will connect To Huntington Sewer When Available
10	0/245	0/518	0/6,240	Ferron Sewer	Ferron Sewer	0/2,300	0/24,840	-/O	
11	0/48	10/1,248	120/14,980	Irrigation	Irrigation*	80/1,420	2,080/36,920	-/O	*Blood To Irrigation
12	0/0	0/0	0/0	Chem. Toilets	Ponds	0/200,000	0/6,000,000	-/1	COE Appln. 6-3-74

Table 7. Continued.

EXPLANATION OF TABULATIONS

NOTES: [a] Also known as Castle Valley Meat Co.
BOD - Biochemical Oxygen Demand

COLUMNS 4 5 6 - NUMBER TO LEFT OF SLASH - The estimated quantity of BOD produced from sanitary wastes in pounds per operating day, per month, and per year (based on 0.1 lb. per employee per operating day).
NUMBER TO RIGHT OF SLASH - The estimated quantity of BOD produced from process sources in pounds per operating day, month, and year.

COLUMNS 7 8 - KEY TO SYMBOLS

CS - Septic tank.
IS - Subsurface wastewater application to land.
KC - Chemicals used.
LE - Evaporation lagoons (non-overflowing).
LP - Lagoons for settling of wastewater.
LPE - Evaporation lagoons for settling of wastewater (non-overflowing).
P - Ponds

COLUMNS 9 10 11 - NUMBER TO LEFT OF SLASH - Pounds of BOD discharged from the plant in sanitary waste per operating day, month, and year.
NUMBER TO RIGHT OF SLASH - Pounds of BOD discharged from the plant in process waste per operating day, month, and year.

COLUMNS 12 13 - Indicates the ultimate disposition of the waste following its discharge from the plant.

COLUMNS 14 15 - Gives the estimated volume of waste discharged in gallons per operating day and month. Sanitary wastes have been estimated at 10 gallons per person per day.

COLUMN 16 - NUMBER TO LEFT OF SLASH - Existing water uses downstream from the point of waste discharge.

B - Source of industrial water supply.
C - Livestock water supply.
D - Irrigation water supply.
F - Game fishing.
H - Wildlife.
I - Bathing.

NUMBER TO RIGHT OF SLASH -

X - Treatment needs presently undetermined.
0 - New treatment facilities needed.
1 - Enlargement of existing facilities needed.
2 - Addition of other treatment methods to existing facilities needed.
7 - No project needed.

SOURCE: Adapted from; "Industrial Wastewater Facilities in Utah," 1975 update to 1973 inventory. State of Utah, Dept. of Social Services, Division of Health, S.L.C., Utah.

and Green River City, that the wastewater facilities in the Carbon-Emery area are inadequate. This inadequacy further complicates the water resource situation by lowering the quality of the available water. This resource contamination in effect removes water from the total available culinary supply.

In the industrial section four of the twelve wastewater facilities are either adequate or undetermined at this time. All others are inadequate to meet wastewater discharge standards.

Water challenges

At this time there is no good quality culinary water, i.e., without treatment, available for an expanding population in the Carbon-Emery area. If treatment plants are constructed, water will be available provided that the water rights can be secured. The relative high prices paid for water rights by new industry in the area has resulted in many owners of water rights "holding out" for the highest bidder. The towns, especially in Emery County, may not have a large enough tax base to outbid large corporations for the available water rights. If water rights cannot be secured through the open market, a city may condemn the water rights needed to provide culinary water for the expanding population. This process of "Eminent Domain" could be exercised by any city or town. The owner of the condemned water rights would receive just compensation at the fair market value.

The only conclusion to be drawn from the available data on water in the Carbon-Emery area is that there simply is not enough to go around. The present culinary systems are barely adequate to meet present average daily demands and cannot meet present peak demand loads. They, therefore, will not be able to supply culinary water for the expected population growth in the area unless some present uses of water are curtailed. The most likely candidate is agriculture.

Figure 8 shows the approximate acreage presently under irrigation in the Carbon-Emery area. Figure 9 for comparison shows the potential

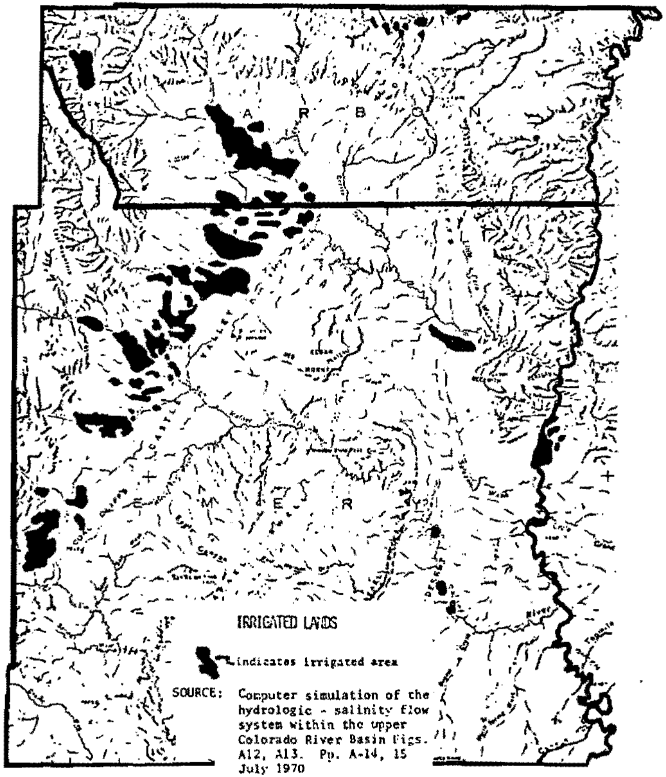
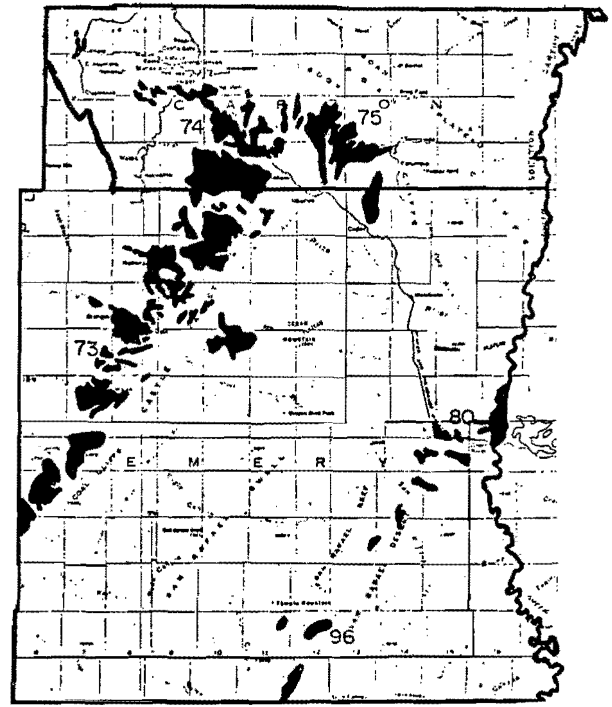


Figure 8. Irrigated lands.



SOURCE: Adapted from, "Arable Land Resources of Utah," Utah Resources Series 42, Utah State University Feb. 1968.

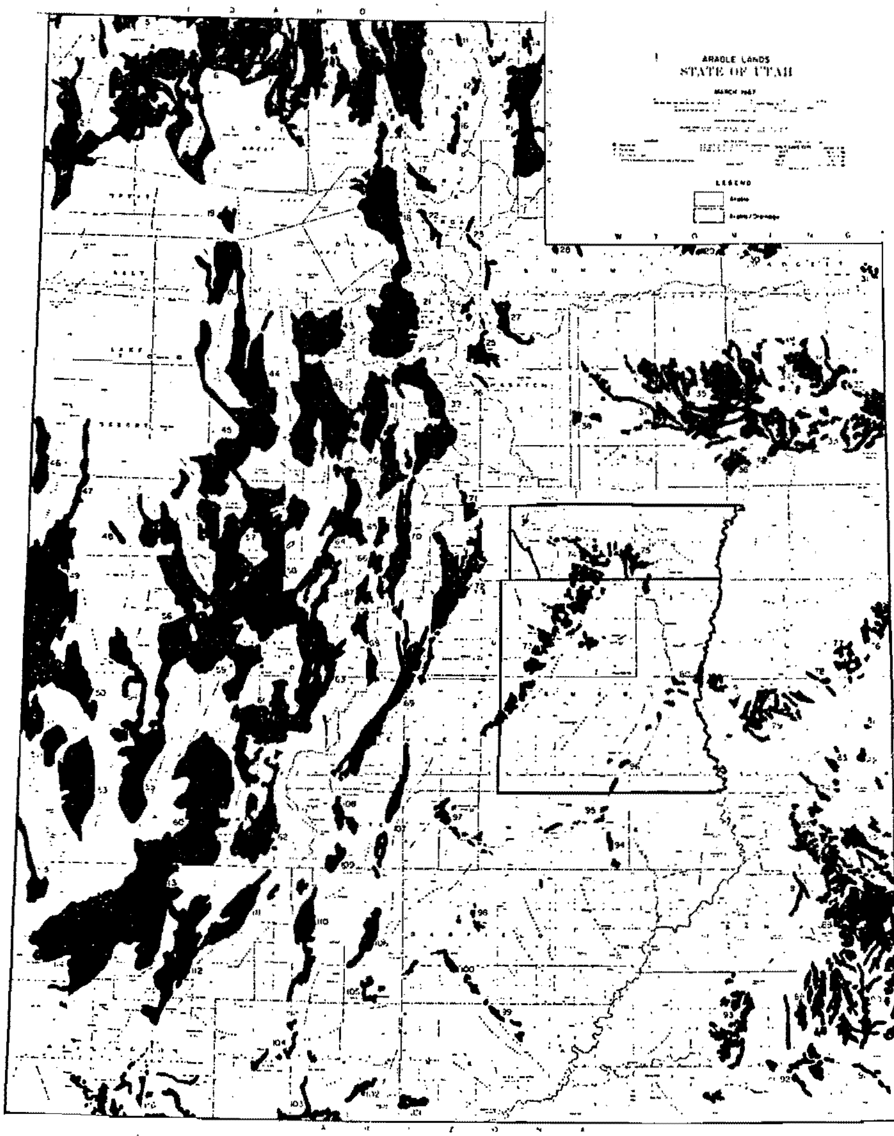
Figure 9. Arable lands.

arable lands for the same area. It appears as if most of the possible arable lands in the Carbon-Emery areas are already under cultivation. When the limited sources of water for irrigation are considered then the present agricultural effort can be termed a near maximum effort. For any increase in agriculture to occur there must first be made available new sources of water. The possible source of this "new" water could be from an interbasin transfer. This, however, would be a costly project and it has already been pointed out that the tax base in the Carbon-Emery area is not large enough to supply the necessary funds.

The effects that a decreased agricultural effort in the Carbon-Emery area would have on the State would probably be minimal. This conclusion follows from the data reported for agricultural production contained in Table 4. Also, Figure 10 shows the possible arable lands for the entire State. From this figure it can be seen that the real agricultural potential in Utah is in the western and northern areas of the State. The Carbon-Emery area contains a small percentage of the total arable lands. Figure 5 adds further support to this conclusion. This figure points out that there are no known or probable ground water resources in the Carbon-Emery area. The correlation between ground water resources and possible arable lands again points to the western and northern areas of Utah as probably the best potential agricultural areas in the State.

How do the above statements or points relate to the agriculture-industry conflict? The answer is that there is a minimum degree of conflict.

This was confirmed in an interview with planners from the southeastern Utah Economic Development District in Price, Utah (8). They agree that there is no present conflict between agriculture and industry, and with proper planning and cooperation between affected parties there should not be any conflict in the future.



ɔE: Adapted From, "Arable Land Resources of Utah," Utah Resources Series 42, Feb. 1968

Figure 10.

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WATER SUPPLY FOR THE HUNTINGTON AND EMERY STEAM ELECTRIC PLANTS

by

F. N. Davis*

Introduction

It is a pleasure to meet with you today to present some genral information concerning the acquisition of water for Utah Power & Light Company's generating plants in Emery County, Utah. In addition, I would like to take this opportunity to briefly discuss the importance of low cost electrical energy now and in the future and to comment on the application of cost-benefit studies in the development of environmental goals and regulations.

Utah Power & Light Company serves a population of some 1.25 million in most of Utah, southeastern Idaho, southwestern Wyoming, and portions of southwestern Colorado for a total area of about 82,000 square miles. Figure 1 outlines the area and shows our backbone transmission lines and our interconnection with 12 other utilities located to the north, south, east, and west of our system. Our generating capacity totals about 1.78 million kw. About 93 percent of our generation is supplied from fossil fired steam generating units located principally in seven plants with the remaining 7 percent being generated by hydro.

Table 1 indicates the category of users we serve at Utah Power & Light Company. This data covers 12 months ending October 1975.

Based upon the 1970 Census, Utah Power & Light Company serves approximately 79 percent of the population of the State of Utah and through agreements wheels government power over our transmission lines to an additional 18 percent of the state's population.

*Utah Power and Light Company.

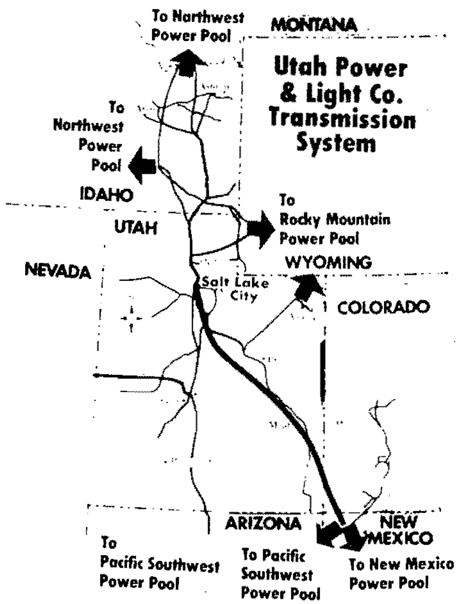


Figure 1. Utah Power and Light Company Transmission System.

Table 1. Utah Power & Light Company customer uses.

CATEGORY	PERCENTAGE OF TOTAL
RESIDENTIAL	25.20
COMMERCIAL	17.00
INDUSTRIAL	30.70
IRRIGATION	5.10
SALES FOR RESALE	17.60
OTHER	4.40
TOTAL	100.00%

The following figures are shown to illustrate some of these categories: New residential (Figure 2), IRS Ogden (Figure 3), LDS Office (Figure 4), McKay Hospital (Figure 5), Western Electric (Figure 6), Rogers Brothers Potato Processing (Figure 7), Oil Refinery (Figure 8), Freeport (Figure 9), Brush Wellman, Inc. (Figure 10), and sprinkler irrigated farm (Figure 11).

Until the late '20's our system was almost 100 percent hydro. Steam electric plants, principally coal fired, now generate most of our energy requirements. Alternative types of generating capacity that are being considered are nuclear, geothermal, and solar. However, for the 1974 to 1985 period, coal fired generation is our only certain alternative and in the 1985 to 2000 period both coal and nuclear will be alternatives.

Huntington Plant water supply

The plant is located in east central Utah about 110 miles south of Salt Lake. The next slides (Figs. 12, 13, and 14) show the first unit of the plant that has been built at the mouth of Huntington Canyon.

A firm 23,000 acre-ft. of water per year has been acquired for the Huntington Site. By purchasing approximately 20 percent of the irrigation rights in the Huntington River and construction of a 30,000 acre-ft. reservoir about twenty miles upstream from the plant in Huntington Canyon (Fig. 15) a firm supply of 12,000 acre-ft. per year was acquired. By purchasing approximately 20 percent of the irrigation rights in the Cottonwood River and the purchase of 6000 acre-ft. of water from Joes Valley Reservoir an additional firm 11,000 acre-ft. of water can be utilized at either the Huntington Plant or the proposed Emery Plant. This water is utilized at Huntington by exchange, that is, by delivering Company owned water from Cottonwood and Joes Valley through an existing irrigation canal to the irrigators in the Huntington Area and utilizing the Huntington Irrigators' water for the Huntington Plant, water from one drainage system can be effectively transferred to another. An additional 3000 acre-ft. per year firm supply will be obtained by storing or using winter flows in the Huntington River. It should be noted that the 26,000 acre-ft. per year when fully used will constitute only about 21 percent of

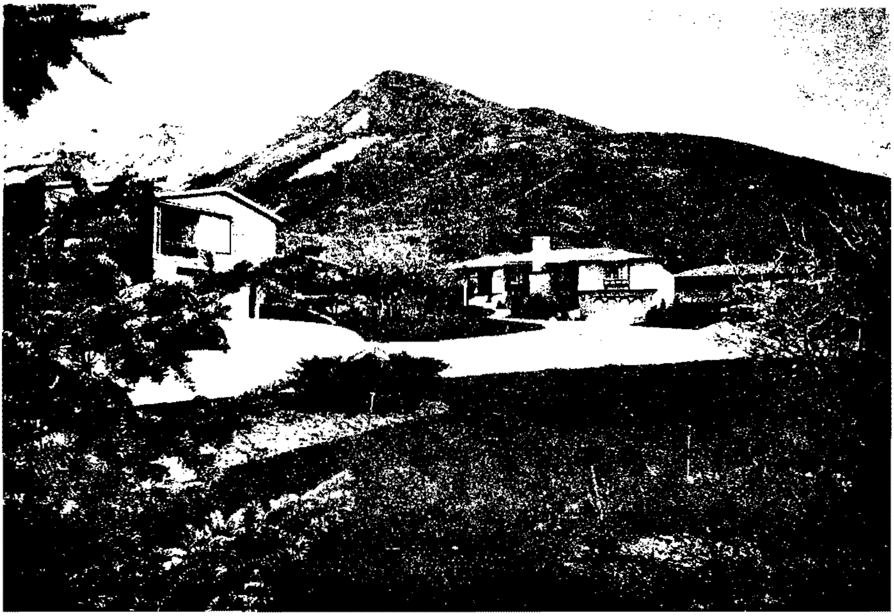


Figure 2.

Figure 3.

Figure 4.

Figure 5.

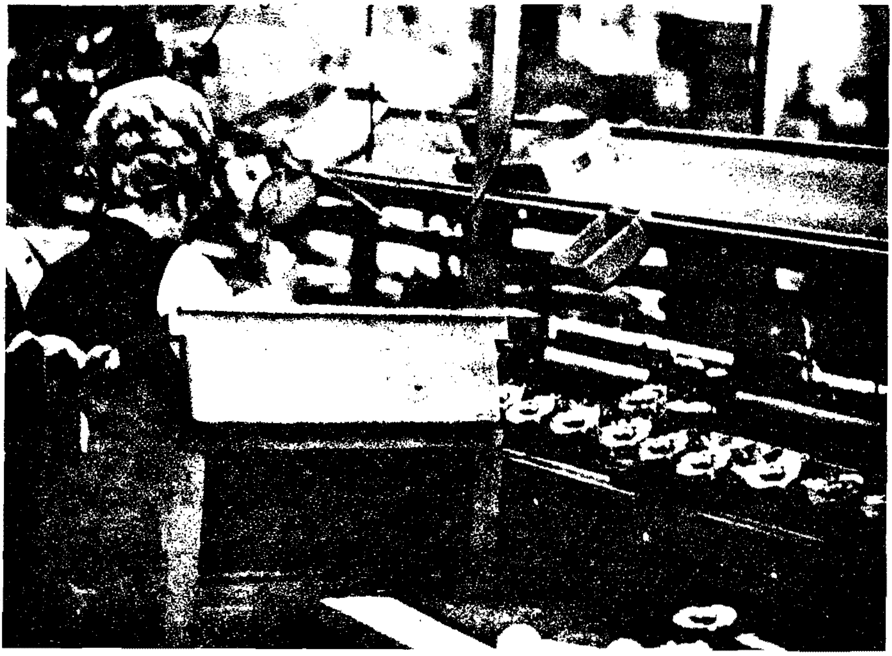


Figure 6.

Figure 7.

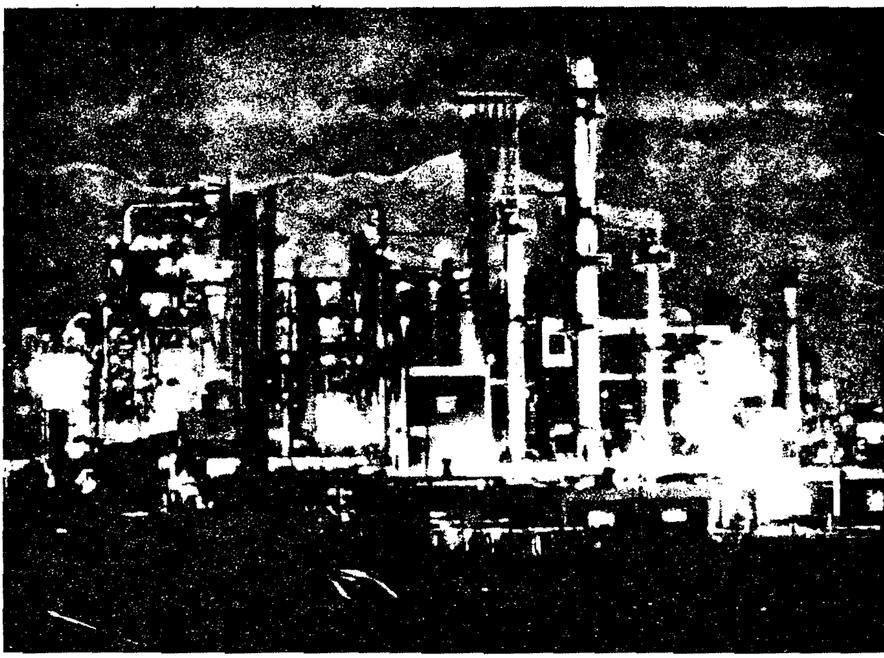


Figure 8.


Figure 9.

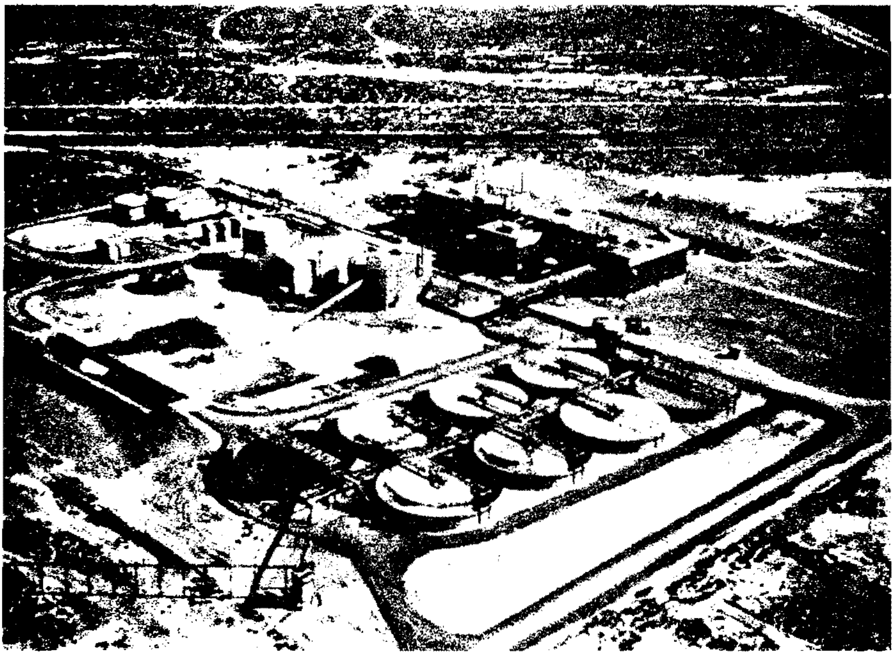
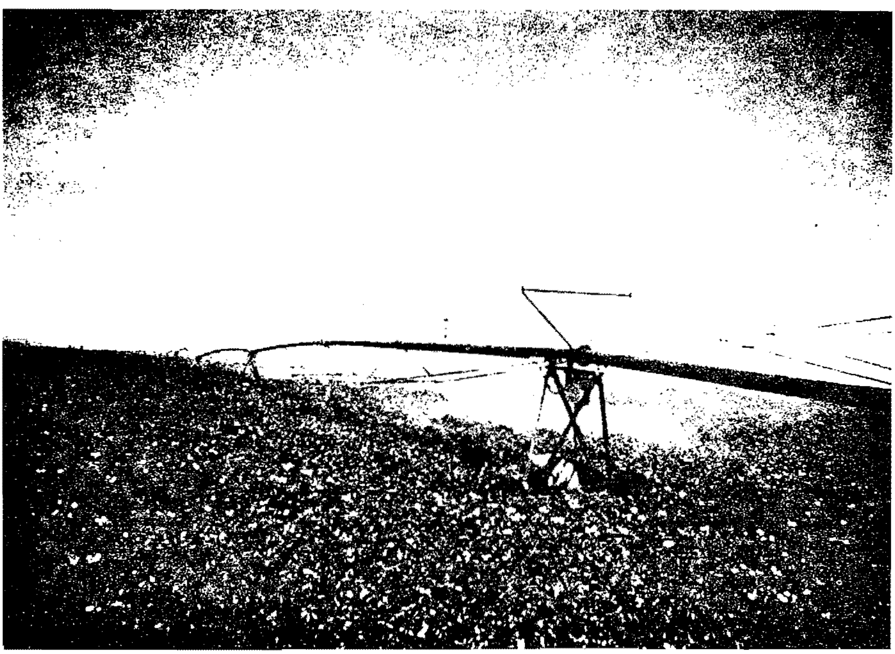


Figure 10.



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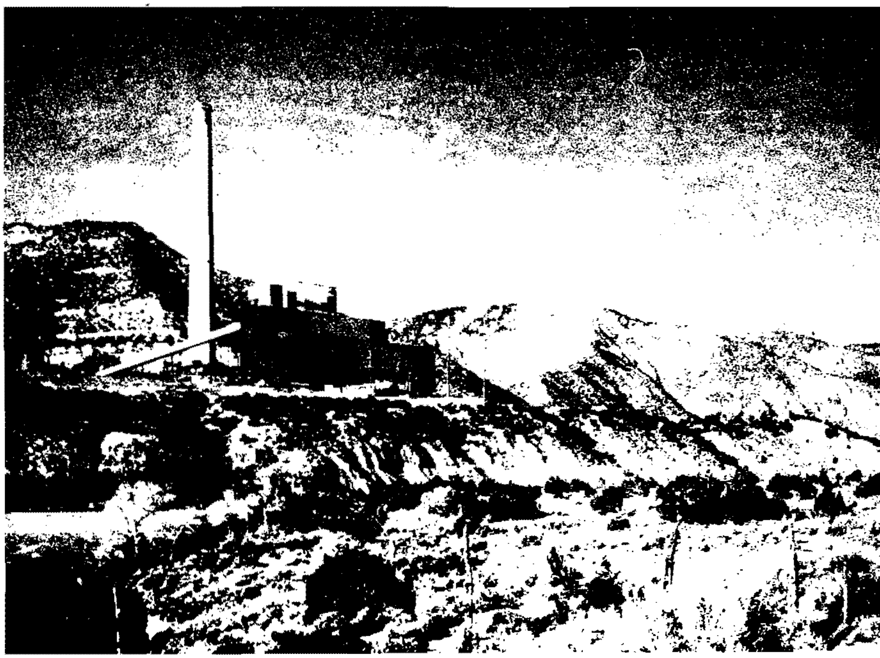


Figure 12.

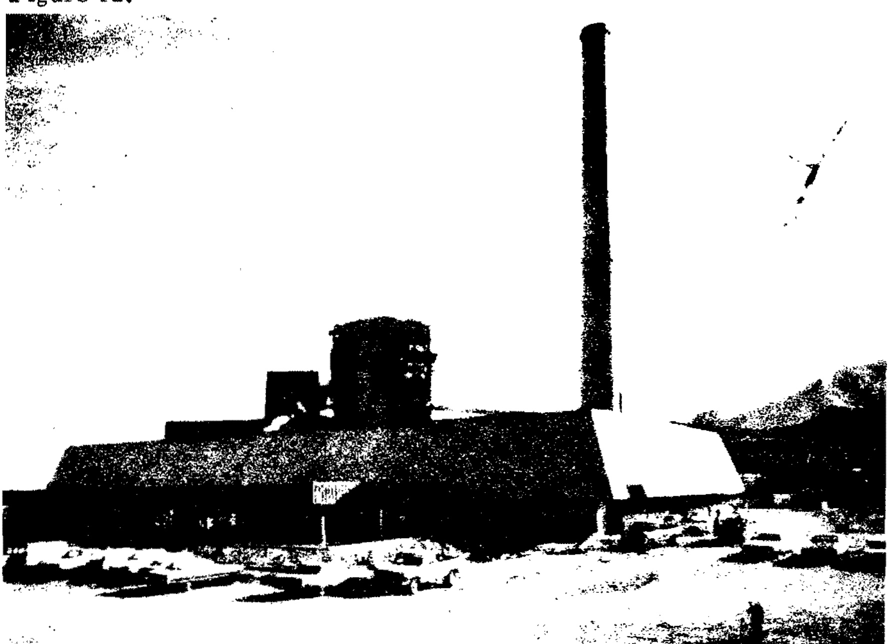


Figure 13.

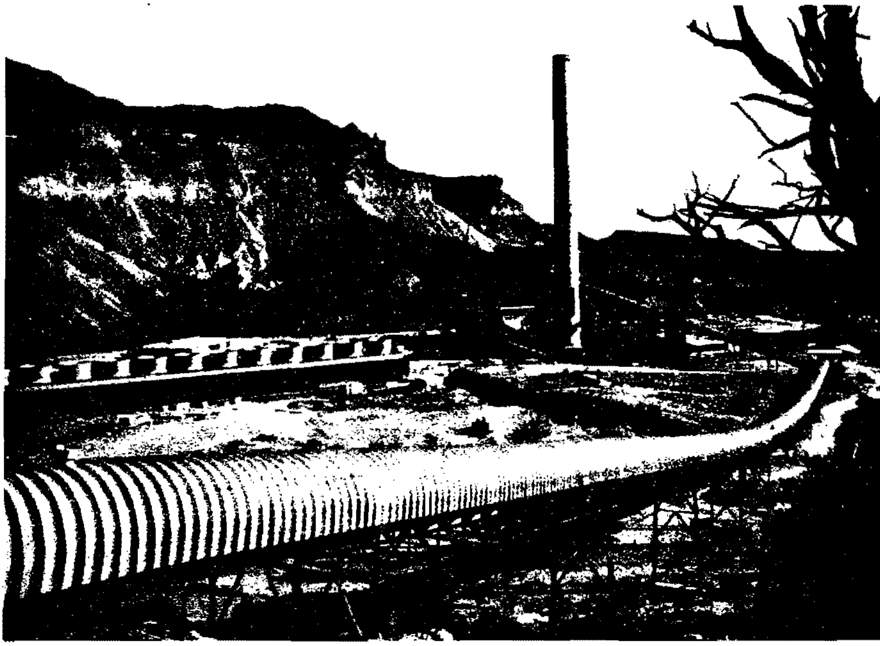


Figure 14.

Figure 15.

the average flow in the two rivers and 0.2 percent of the water originating in the Upper Colorado River Basin. We believe this is a good blend of irrigation and industrial use. Although in dry years some marginal irrigated land will have to be taken out of use, with more efficient water utilization there will be little effect on total farm production.

Emery Plant Water Supply

The Emery County plant site is located about 15 miles south and east of the Huntington Site. The two-400 mw unit plant is essentially a duplicate of the first two units at Huntington. The first unit is scheduled for service in 1978 and the second unit is planned for 1980.

We have signed a contract with the Ferron Canal and Reservoir Company for purchase of a firm 7,000 acre-ft. water supply from the Millsite Reservoir on Ferron Creek. This water would be piped from the reservoir to the plant site, a distance of approximately ten miles. We believe that the 7000 acre-ft. supply will be sufficient for two-400 mw at the Emery Site with utilization of wet-dry cooling towers. Present studies indicate the wet-dry tower would be the economic choice. However, this possibility is still being studied.

Future Water Requirements

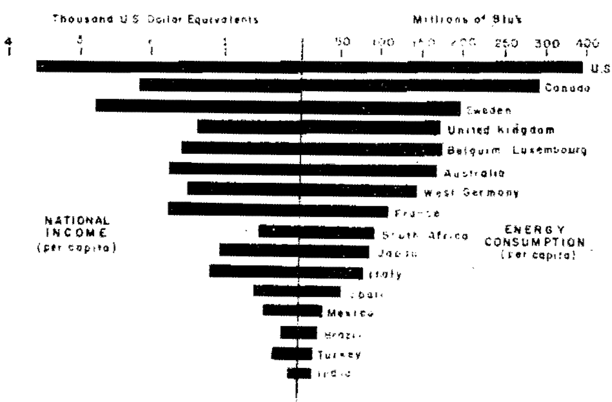
Table 2 summarizes the projected steam electric power plant capacity and the estimated water requirements for a particular year through the year 2000, assuming that all new steam electric additions beyond that presently projected or existing in Wyoming will be constructed in Utah to the turn of the century. An 80 percent capacity factor is assumed for future plants. (It may be of interest to note the consumption of coal for those units shown, up to and including the year 2000 would be at least 220 million tons. This would be about 2.8 percent of the Utah recoverable coal reserve, estimated by the Utah Geological Survey to be some 7800 million ton.)[1]

Table 2. Utah Power & Light C mpany Utah steam electric plant estimated water requirements (acre-feet annually).

DATE	STEAM CAPACITY (MWE)	CONVENTIONAL TOWERS	WET-DRY TOWERS
1974	934	11,200	
1977	1,349	18,200	
1978	1,764	25,200	21,700
1980	2,179	32,200	25,200
1994	4,989	79,500	48,900
2000	8,000	130,300	74,300

ASSUMING ALL NEW GENERATING UNITS (BEYOND THOSE PRESENTLY PROJECTED FOR WYOMING) TO BE COAL FIRED AND LOCATED IN UTAH.

PER CAPITA INCOME AND ENERGY CONSUMPTION, 1968



Source: U.S. Department of the Interior, 1972. United States Energy—A summary Review, Washington, D.C.: U.S. Department of the Interior, p. 2

Figure 16.

The free economic system has served the company and people of Utah very well in the past. We believe this was illustrated in the acquisition of water for Huntington and Emery. I would hope the government would allow this system to operate when possible.

Importance of Low Cost Energy

Although only indirectly pertaining to water, I would like to remind each of us that low cost electrical energy is important now and may be even more important in the future.

At Utah Power & Light Company, we are basically converting raw energy resources - primarily coal - at this point in time to a more useful form of energy and transmitting this energy to the point of utilization.

It has been calculated that the average power a man can exert is about sixty watts.[2] Using that figure, the average household (in Utah) has the equivalent of fifteen servants working around the clock. Even more significantly, assuming a factory worker performs 240 eight-hour days of manual work per year, the average factory worker in this country in 1973 had the equivalent electrical energy of 390 men helping him on his job all year long. Each U.S. farmer produces food for fifty-one persons.[3]

Some are predicting that by the year 2000 some 40 percent of raw energy resources will probably be used to generate electricity as compared with about 25 percent now.

Figure 16 shows the relationship between raw energy utilization in all forms and income (or standard of living) for a number of Western Nations in a recent year. The direct relationship is unmistakable. We simply must have energy as the motive force to produce the goods and services required to feed, clothe, house, and transport modern society and hopefully provide a few of the so-called luxuries of life.

Figure 17 shows the use of fossil energy for the past 6000 years and projects use for the next 6000 years, covering a 12,000 year span of mankind on this earth. Truly, we have been living in a Camelot which

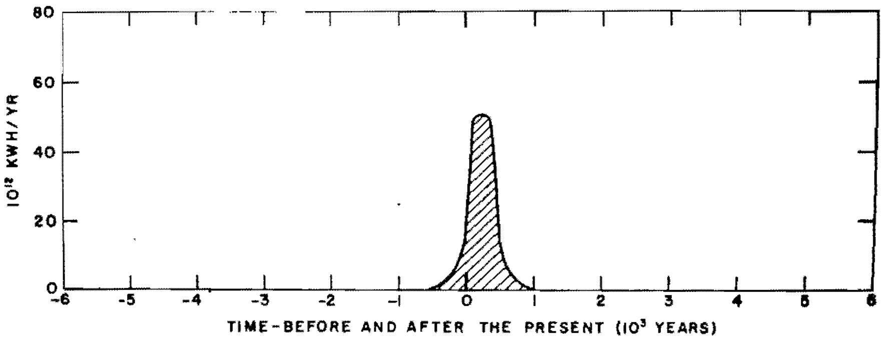


Figure 17.

WORLD FUEL SUPPLIES IN YEARS

	USAEC	HOLDREN	HUBBERT	NAS
GAS	27	22	49	50
OIL	30	38	70-80	50
COAL	200	122	100-400	300
OIL SHALE		6000	10-100,000	
URANIUM	30			
(BREEDER)	2000			
D_2(FUSION)	2 Billion			

Figure 18.

cannot continue without substitute energy forms, such as the nuclear breeder, solar or fusion.

Figure 18 shows various estimates of the life of various fuels. It appears that we have a coal supply for at least one hundred years and with the breeder, nuclear fuel for some 2000 years. I am personally confident that man has the ingenuity to develop solar, fusion or other forms we may not dream of so that mankind may have the energy to survive and possibly to improve the quality of life we enjoy.

Figure 19 and 20 illustrate it is possible to heat a home or drive an automobile with coal or nuclear fired power plant, replacing natural gas and gasoline in shorter supply and using less basic units of energy. The technology is here and will remain an alternative for hundreds of years in the future.

Although we have the technology to electrically drive automobiles, and perform most other functions of energy in the production of goods and services, such functions may not be economically feasible for many of us if we increase costs of producing electricity that are not really justified.

Cost-benefit

Now my third and last point. I would like to suggest that each of you in your areas of influence carefully consider both the costs and benefits resulting from regulations pertaining to electric and other energy industries.

For example, we believe prudent expenditures for environmental values are proper and in the best interest of our customers and the general public. However, a basic test of prudency is having some knowledge of the costs and resultant benefits of expenditures.

Over a period of at least four years, Utah Power & Light Company has suggest to regulatory Government Agencies that pollution control regulations or controls should be based on cost-benefit relationships to

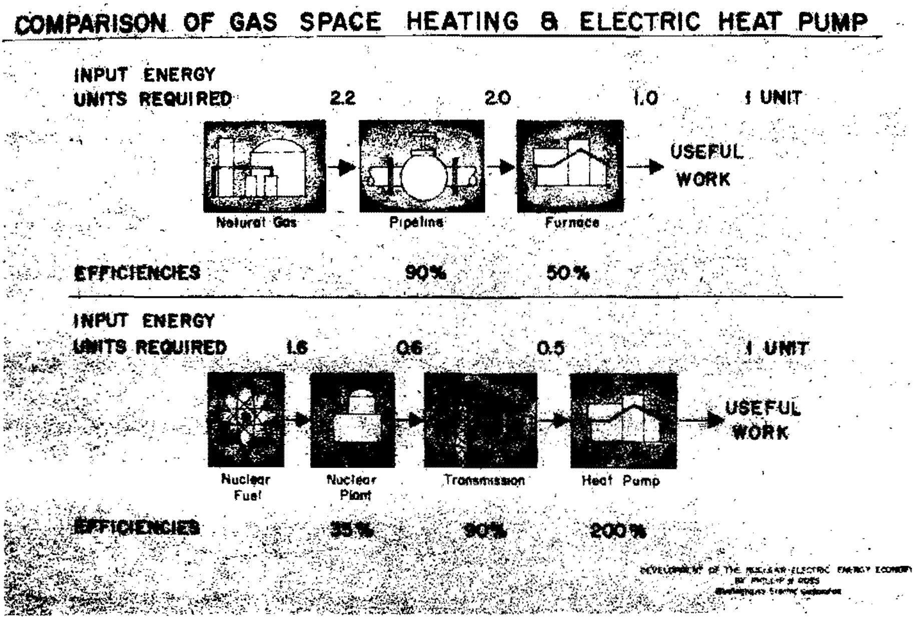


Figure 19.

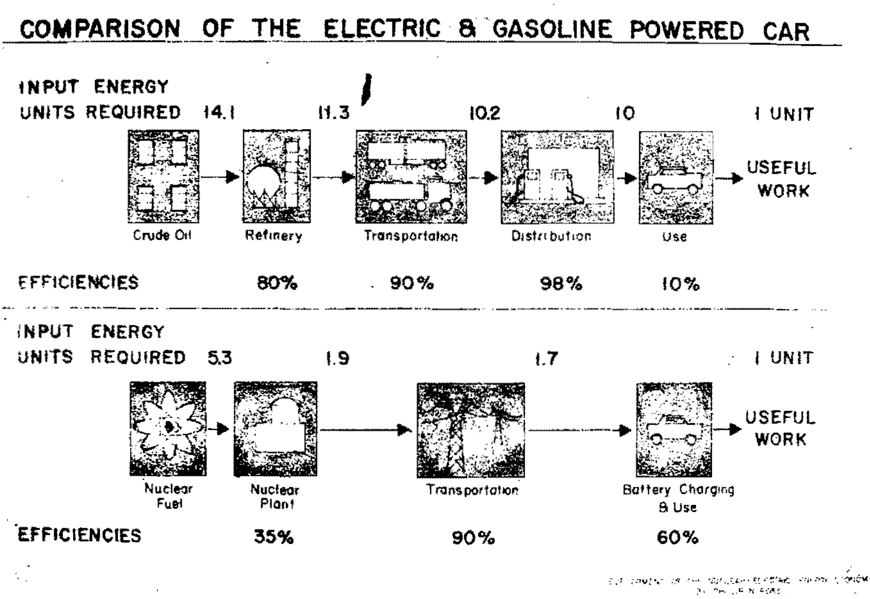


Figure 20.

provide a better understanding and quantification to vague guidelines such as "best available control technology."

Let me give just one example pertaining to water resources: The United States Bureau of Reclamation has recently produced a report entitled "Economic Impacts of Changes in Salinity Levels of the Colorado River." This report indicates the probable value to irrigated farms on the Lower Colorado of reducing or increasing concentration is in the order of $230,000 per year per ppm. This is precisely the kind of study which simply has to be performed in order to justify a zero discharge policy on the Colorado and other rivers.

Dr. Donald C. Grey and Dr. Vaughn E. Hansen, environmental and engineering consultants to the company, have gathered available salinity data and calculated, based on the Bureau of Reclamation Study, the value of the zero discharge policy for two units at Huntington.[4] They conclude the benefit of zero discharge to Lower Colorado water users in the range of $30,000 per year. The annual cost to power users would be about $650,000. This is one dollar saved for some twenty dollars spent.

It is to be understood that our studies are only preliminary. We are ready to be convinced otherwise if our analysis or data is in error. I bring this particular cost-benefit study to your attention now with the suggestion that such cost-benefit studies be made by appropriate governmental authority before enacting regulations or establishing goals such as a "zero discharge waste water policy" or "use best available technology" without defining what "best technology" really is.

Again, we may be overlooking some important value in this particular example. However, if these present studies are even approximately correct, I am at a loss to explain why industry should desalinate water when agriculture obviously can't. Who is bearing the costs? Of course the answer is that we all are, whether through consuming the products of agriculture or the products of industry.

There is no doubt that a zero liquid waste discharge concept is technically possible. I have some very great doubts that such a policy is practical or in the interest of the general public, as the Huntington example illustrates.

This is only one example pertaining to water resources. I could give others in regard to air quality or the location of transmission lines.

Summary

This afternoon, I have tried to make three points:

1. Water for industry can be acquired not in conflict with agriculture, but with a reasonable blend under free market conditions.

2. Energy is important to our quality of life and all of us should be concerned about its availability and cost, and

3. A cost-benefit analysis is a valuable method to check the reasonableness of environmental regulations and goals.

Thank you for the opportunity of speaking at this meeting. I hope our experience is of interest and provokes some response to the thoughts expressed.

References

1. Utah Geological and Mineral Survey. Monographs 1, 2, and 3 (1973).

2. Energy Resources of the World, U. S. Department of State Report 3428 (June 1949), p. 124.

3. Questions and Answers about the Electric Utility Industry. (Edison Electric Institute, New York, 1973), p. 22.

4. Preliminary Estimates of Salinity Effects and Resulting Economic Impacts of Power Plant Operations in Castle Valley.

5. Dr. Donald C. Grey and Dr. Vaughn E. Hansen, Environmental Consultants to UP&LCo, Salt Lake City, Utah, January 1975.

WATER RESOURCES FOR UTAH OIL SHALE DEVELOPMENT

By

Gary E. Parish*

On behalf of The Oil Shale Corporation, also known as TOSCO. I thank you for this opportunity to participate in a discussion of the implications of energy development for Utah's water resources TOSCO's interest in energy development centers, as our name implies, around the commercial development of oil shale deposits of the Green River formation. Before getting into detailed considerations of the water issues themselves, I would like to first give you some background information concerning The Oil Shale Corporation and its present plans for commercial activity in Utah.

TOSCO is an independent, publicly-owned, energy company, organized in 1955 for the purpose of developing a commercial technology for the recovery of hydro-carbons from oil shale. People have been talking about oil shale since the 1920's--TOSCO has been determined to see this valuable resource developed. In 1955 we were, unfortunately, a lone voice in the wilderness: there were no energy crises, oil boycotts, or OPEC to indicate that shale oil had come of age. Today, The Oil Shale Corporation is the industry leader in shale development technology and a very substantial owner of domestic oil shale reserves. We are currently completing the adaptation of our oil shale technology, together with Goodyear Tire and Rubber Company, for the recycling of scrap tires--a particularly bothersome form of solid waste. TOSCO is also at an advanced state of development of a unique coal processing technology to facilitate utilization of our vast domestic coal reserves as a clean and acceptable energy source.

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*The oil Shale Corporation, Denver, Colorado

Our investments in technology development alone have exceeded by many times any other publicly disclosed effort to develop and demonstrate a technically, economically, and environmentally viable system. We, along with the associates who joined us, have expended more than $55 million dollars in the development and demonstration of the TOSCO II system. In a sustained, large-scale, 1,000 ton/per day field demonstration operation in western Colorado, the following has been accomplished.

-- We have mined underground more than 1.2 million tons of oil shale, using and proving conventional underground mining processes and equipment;

-- We have proven that the TOSCO II process utilizes 100 percent of the ore that is mined, and recovers substantially 100 percent of the assayed hydrocarbon content of the shale;

-- We have demonstrated, more than any other new industrial development project of which we are aware, advanced environmental control measures for our system, encompassing, among other matters, processed shale disposal and surface restoration, air and water quality control, community assistance and planning, and protection of flora and fauna.

In Colorado, TOSCO is a venture participant in two projects which will undoubtedly become first generation oil shale developments. TOSCO and its three partners, Atlantic Richfield, Ashland and Shell were successful high bidders for tract C-b in the federal oil shale leasing program. The same four companies also are participants in the Colony Development Operation on fee lands near Grand Valley, Colorado. Both of these operations will utilize the TOSCO II surface retorting technology. In addition, the Operators of Federal lease tract C-a, have signed a letter of intent toward licensing the TOSCO II technology for their Rio Blanco Oil Shale Project.

The Utah Sand Wash Project

As you can see, The Oil Shale Corporation is more than serious about shale development. In Utah, the White River Shale Operation on Federal lease tracts U-a and U-b also is evidence that the time for oil shale has come. My corporation holds Utah State leases to five blocks of land, totaling 14,688 acres within an 8 x 12 mile rectangle, approximately 30 miles due south of Vernal. This area is known as the Sand Wash Area. The leases require annual rentals with large royalties on production, which are primarily earmarked for support of public schools TOSCO acquired these leases two years ago and immediately undertook a $150,000 program to verify our resource estimates. As a result of that work, we have prepared and submitted to the State Land Board a Preliminary Development Plan which contemplates commencement of construction and operations in the early 1980's of a 75,000 barrel-per-day commercial oil shale complex, which would bring 1,500 new jobs to Utah and increase the state and local tax base by more than $600 milli dollars.

We have submitted to the State Land Board a proposed Unit Agreement and Cooperative Plan of Development in order to unitize the state tracts and to establish a base development area which can be relied upon in carrying out our planning, development, financing, and other activities. Approval of this submission is an essential first step in planning development, and would obligate TOSCO to spend $8 million dollars on development over the next nine years.

TOSCO has also submitted to the Utah State Oil and Gas Board a Notice of Intention to Commence Mining Operations pursuant to its Rule J-3, even though the activities as described in the Notice are not commonly understood to be "mining." These activities include the drilling of up to 21 coreholes to obtain resource and environmental information; the conduct of environmental inventory and monitoring activities; the construction or improvement of a limited number of roads power lines, and shelters necessary for the conduct of these operations;

and other related activities.

Our activities will be in large measure designed to make a detailed environmental assessment as well as to verify information concerning the resources themselves. It should be noted that the Sand Wash Project, if approved, has a substantial lead time in which to incorporate advances in technology, environmental protection, and water resource use and planning.

I have made this rather lengthy introduction to my subject of water resource issues and oil shale to insure an understanding of the development that is actually planned in Utah and to direct your attention to the fact that TOSCO and its Venture partners have spent by far the largest amounts of time and resources in the industry toward investigation and development of answers for problems which have stymied commercial development thus far. It is to be hoped that the differences between Congress and the President over a national energy policy can be resolved at an early date so that numerous energy projects, including the Colony Development Operation in Colorado, can be taken off the back burner with assurances of protection from international economic sabotage.

Water requirements of the Sand Wash Project

Since actual plant and mining parameters will not be selected until a later date, Sand Wash water requirements can only be approximated at this time. The following information should provide an order-of-magnitude for resource planning. A commercial oil shale facility with underground room and pillar mining and the TOSCO II surface retort for the Sand Wash Project would require approximately 12,500 acre-feet of water per year on a calendar day basis (which includes normal downtime).

Total plant requirements on a stream day basis-which represents maximum production characteristics with no down-time-would be on the order of 14,000 af/year. Prudent management will require a secured supply, with a safety margin, to provide for stream day requirements, while actual anticipated uses will be closer to calendar day requirements. Water for mining and crushing would be used to control fugitive dust and would total approximately 1,700 af/year. 7,710 af/year would be consumed in the processing units for such uses as scrubber particulate controls, cooling towers, and upgrading the product to pipeline quality. The remainder, 3,000 af/year, will be used in the processed shale disposal operation for moisturizing in order to control dust and to provide proper handling, compaction, and revegetation characteristics.

A further water requirement will exist for revegetation of spent shale. This demand will primarily occur between the 15th and 25th years after commencement of operation. No definite plans will be made until a much later date based upon environmental and technological studies, as to the types, quantities or methods of surface disposal of processed shale. TOSCO is studying methods for underground disposal and hopes to have developed economical technologies during the lead time of the next decade. By way of anticipation, however, we do know that the 50,000 barrel-per-day Colony operation would, over its lifetime, require about 800 acres of surface area for processed shale disposal and a total of 5 acre-feet of water per acre of processed shale to develop selfsustaining vegetative cover. We can say with some confidence that total revegetation water requirements during the Sand Wash Project lifetime will be less than one year's water requirements for plant needs. Average annual precipitation in the Uintah Basin is 9 to 10 inches.

The final water demand which will be associated with development of Utah's oil shale is the increased domestic requirements which will occur from indirect or direct population growth in the Uintah Basin. We expect the Sand Wash Project to create around 1,5000 permanent jobs with an annual payroll, based on current dollars, on the order of $25 million. There will be an inducement of service-type workers and associated industry into the region as a result of primary employment in oil shale. Naturally, water must be available to meet the needs of residents. We have determined from our planning efforts in Colorado that total new domestic water requirements resulting from an oil shale facility will be roughly equal to 20 percent of the total plant annual requirements. At the most, therefore, an additional 3,000 acre-feet per year of domestic demand will occur in Utah as a result of the Sand Wash Project.

To summarize these figures again: we estimate an oil shale complex to produce 75,000 barrels of high quality oil per calendar day would require 12,500 acre-feet per year for the plant and mine, perhaps an additional 400 acre-feet per year average for surface revegetation, and 3,000 acre-feet per year for associated domestic needs. The total of nearly 16,000 acre-feet per year would require a water in-flow of about 25 cubic feet per second (cfs).

Water supply for the Sand Wash Project

There are many possible water supply sources for oil shale development in Utah. Water is physically available in the White and Green Rivers and in as yet undetermined quantities and qualities in groundwater form. Part of the studies to be undertaken during our lead time prior to commercialization will be to acquire sufficient information about the availability and desirability of alternative water supply sources. It is no overstatement to suggest that there are also legal, social, and economic complications associated with any new water use. The last half of this paper will explore some of those complexities. Water is a scarce and dear commodity in an arid environment. The last decade has forced the nation to the realization that we must understand and live in harmony with the environmental web that sustains life mechanisms. The next decade will certainly educate the nation about the vital role of water in the western environment. Water is not only a scarce, indispensible element in our arid environment, it also supports economic activities which give fullness and meaning to our lives. It is evident that we all face the challenge of determining the wisest use of our water resources. Governor Rampton has stated that water will be available for the development of this state's oil shale resources[1]. My company will certainly do everything in its power to cooperate with state and local officials to insure that whatever water we would use is used wisely, efficiently, and without detriment to present users.

TOSCO has filed applications for 25 cfs (cubic feet per second) from both the White and Green Rivers with the State Engineer. We are also examining the possibility of purchasing water from the Indian reservations bordering the Sand Wash properties. Coreholes and aquifer testing during the period prior to commencement of operations will define the groundwater characteristics in that part of the Uintah Basin. We are also studying the possibility of using sour and saline waters from conventional oil and gas operations in the basin as the moistening agent for processed shale disposal: success here would not only lessen water demands for oil shale, it would also solve an obdurate water quality problem of conventional energy production.

There are several aspects of oil shale water use which all too often receive short shrift in discussions concerning water availability and environmental impacts. The first consideration is the degree of future commitment involved. The Sand Wash Project would have a relatively short lifetime compared to other water uses. After 25 years the reserves will have been exhausted and the useful life of the plant at an end. The water will again be available for other beneficial uses.

The second consideration is that only a small part of the water can be considered permanently removed from the aquatic eco-system. Although we speak of water as being "totally consumed," that phrase should be properly understood as meaning that there will be no return

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[1] See, The Denver Post, October 13, 1974, p. 2.

flows to surface streams, and therefore no resulting pollution. Most of the water we use will be returned to the environment through evaporation.

A final consideration for supplying an oil shale facility with water is that the supply must be constant throughout the year. This single supply characteristic has been the toughest issue for new industrial demands in the west. We have all been told on numerous occasions that the rivers are "over-appropriated." One thing this phrase has meant is that during the summer months when the streams and rivers experience their lowest natural flows the demands of agricultural water users are the highest--often beyond what the surface flow can provide. An industrial user, arriving on such a scene, will discover that he can obtain a good water right for six to eight months out of the year, but that argicultural users with earlier priority water rights will "call him out" during the remainder of the year. There are several alternatives available to solve this short supply problem. Resolution of relative costs and benefits for each alternative --including social, economic and environmental factors--must proceed on a case-by-case basis for each new user. The alternatives can be grouped as follows:

(1) Develop, either publicly or privately, a water storage project to release stored rights to make up direct flow shortfall;

(2) Contract with existing public or private water storage projects for a share of the water to be released upon call;

(3) Explore for and secure deep, non-tributary ground water for use as a supplement;

(4) Buy out early priority water rights and transfer them to the new use (without harming other junior appropriative rights); and

(5) Possibly utilize a program of groundwater withdrawal combined with a program to augment surface flows similar to

that used in Eastern Colorado along the Arkansas and South Platte Rivers.

TOSCO is hopeful that the Green River will prove to be a dependable source with no additonal storage required for industrial demands. If such should not prove to be the case, then we will have to address the alternatives.

Energy and Water Resource Issues

It might prove useful to explore some of the more generalized water resource issues connected with energy development. In essence there are only two aspects to the water question: the availability of water and the impact of energy development uses on existing uses and on the eco-system.

(1) Water availability

TOSCO's studies, alone and in cooperation with other including the government, indicate current water availability sufficient to support substantially more than one million barrels per day of production, including related intrastructure growth in Colorado, Utah and Wyoming. Since it is our view that second generation plants will be unlikely to refine shale crude oil in the field and there are options for substitution of air-cooling for water-cooling, we regard that projection as conservative. I would not want to suggest by the foregoing the we or anyone else knows exactly how much water can be made available for oil shale development. I would suggest that the picture is not as bleak as that portrayed by some.

Utah in 1970 was not utilizing 107,000 acre feet of its compact share even after subtracting committed future uses for reclamation projects, Indian lands and coal-electrical generating plants in Southeast Utah.[2]

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[2] U.S. Department of the Interior, Final Environmental Statement for the Prototype Oil Shale Leasing Program, 1973, Vol. I, pp. I-11 to 29.

The mere fact that water is not presently being used in no way settles the question of its availability for energy production.

> The fact that there is presently unused water in the Basin does not necessarily mean that there is unappropriated water, but, rather, that the water may not be available at the proper time or place to satisfy the existing rights or that there is inadequate storage capacity of the streams to properly manage the water supply.[3]

Daniel Lawrence and Dee Hansen have provided this Conference with further valuable insights into the convoluted issue of making western water available for energy production without destroying existing economies and eco-systems.

The issue of water availability is in reality an issue of making presently unused water available at the right times and places and for the most socially desirable undertakings. Due to the capital-intensive nature of an oil shale facility, developers must be able to demonstrate low-risk feasibility to compete in financial markets. Unfortunately, there are several legal and institutional problems in western water law which substantially and unnecessarily increase risks associated with obtaining secure water supplies.

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[3] U.S. Department of the Interior, Water for Energy Management Team, Report on Water for Energy in the Upper Colorado River Basin, July, 1974, p. 27. I would also direct your attention to the following studies for additional analysis of the issues of water supply for expanding energy development:

> USGS Circular 703, Water Demands for Expanding Energy Development, (Davis and Wood, 1974).
>
> U.S. Water Resources Council, Water for Energy Self-Sufficiency, August, 1974.
>
> U.S. Bureau of Reclamation, Upper Colorado Region, Salt Lake City, Utah, Alternative Sources of Water for Prototype Oil Shale Development, Colorado and Utah, September, 1974.
>
> National Petroleum Council, U.S. Energy Outlook: Water Availability, 1973.

Storage projects

As pointed out before, many industrial water users must have an assured year-around supply. While acquisition and conversion of early agricultural rights provides the most certain means of obtaining water, the social and environmental effects of such actions entail unwanted consequences. Public water storage projects have always provided the better solution: water was made available for various classes of users, along with secondary public benefits of flood control, recreation, and power generation.

We seem to have reached a point in our history, however, where the problems associated with obtaining water from, or construction of, publicly-funded water storage projects equal or outweigh the benefits. One problem for new projects is simply that of time. The Bureau of Reclamation has advised interested parties in water projects in Western Colorado that a minimum of eight years is required for reconnaisance, plan development, environmental impact statement, authorization, appropriations and construction. All of the Federal prototype oil shale leases lie within the White River Basin where there are no present storage projects. The Federal lessees will be prepared to start construction of their complexes in 1978 and operations in 1980, however.

A further set of problems for any form of storage project can be found in the decreasing number of promising sites which do not involve the destruction of valuable scenic and/or wildlife habitat areas. Surface evaporation must always be considered. The development of private, single-purpose storage appears to be the only viable alternative in some cases, yet the prospect of uncoordinated development of private projects limited to single purposes runs contrary to dearly-held beliefs about efficient and beneficial useage of our limited resources.

If public storage projects containing municipal and industrial (M&I) water already exist on a river system adjacent to oil shale deposits (e.g., Ruedi and Green Mountain in Colorado and Flaming Gorge in Wyoming), they seemingly offer the perfect solution for contracted augmentation supply. Complications are never far over the horizon! In this case they are threefold: (1) an environmental impact statement of the entire Complex will be required, even though the project may be entirely removed from Federal lands; (2) litigation by private parties seeking environmental protection goals or alternative uses for project water; and (3) potential application of a proposed Water Resource Use and Management Policy Statement of the Department of the Interior.[4]

An example of litigation can be seen in that between the Environmental Defense Fund (EDF) and agricultural users on the one hand and the Bureau of Reclamation on the other over contracts for coal water supplies from Yellowtail Dam in Montana.[5] The proposed Policy Statement of the Department of the Interior would tend to suggest that as far as the United States Government is concerned, any applicant for public water may be subject to operational controls rather than merely the agreed-upon price.

Interstate compacts and treaties

There is a tendency to approach the issue of water availability in a mechanical manner: i.e., to simply review the laws of Utah or Colorado to determine the procedures that must be followed to obtain and secure a water right. Such an approach may prove inadequate; of equal importance in an era of exhaustion of unused water is "The Law of the River", the subject being addressed today by Mr. Crawford and Mr. Weatherford. The law of the Colorado River, often referred to as the most litigated river in the world, is to be found in the Colorado River Compact of 1922,[6] the Upper Basin

[4] 39 Fed. Reg. 44788, (Friday, December 27, 1974).

[5] E.D.F. vs. Morton, Civil Action No. 1220 (D.C. Mont. 1974)

[6] The Boulder Canyon Project Act of 1928, 45 Stat. 1057, 43 U.S.C. 617, granted Congressional approval of the Colorado River Compact. Consent to negotiations was granted by the Act of Aug. 19, 1921, 42 Stat. 171.

Compact,[7] an international treaty with Mexico,[8] an agreement with Mexico of August 30, 1973[9] concerning water quality, and Federal and State case and statutory law.[10]

Despite the lengthy history of negotiations leading to the Colorado River Compacts and subsequent litigation thereon, the remaining ambiguities concerning the availability of water as between Upper and Lower Basins and Mexico are such as to preclude a desirable degree of certainty concerning recently initiated water rights.

The treaty with Mexico obligates the United States to supply 1,500,000 acre-feet per annum at the International Boundary. As you may imagine, water attorneys in each of the Basins have used their talents to argue that this treaty burden on the River should be borne by the other Basin out of its Compact Share. Any definitive answer will certainly require the assistance of the United States Supreme Court.

A further difficulty in determining water availability in the River is that the 1922 Compact was based upon the erroneous assumption that the average annual flow of the River was 20 million acre-feet. Records now indicate that the actual historic flow of the Colorado is closer to 12-13 million acre-feet per year. Unfortunately, ambiguities within the Compact and the Act approving the Compact leave no certainty as to which parties are to bear the burden of nature's deficit. A review of some of these ambiguities will demonstrate the intractable nature of the problem:

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[7] Act of April 6, 1949, 63 Stat. 31.

[8] Treaty Series 994, 59 Stat. 1219.

[9] Minute No. 242 of the Int. Boundary and Water Commission, United States and Mexico.

[10] See, especially, Ariz. vs. Calif., 373 U.S. 546 (1963) (decree at 376 U.S. 340 (1964)), and the Colorado River Basin Project Act of 1968, 82 Stat. 885, 43 U.S.C. 1501, as amended.

--California agreed to limit its use of the River to 4,400,000 acre-feet per annum.

--Article VIII of the Compact states: "Present perfected rights to the beneficial use of waters of the Colorado River system are unimpared by this Compact..."

But the effective date of the Compact has been claimed from among the following:

(a) November 24, 1922--Compact signed by Commissioners; never ratified by all seven states as required by the Act of August 19, 1921 (42 Stat. 171) consenting to compact negotiations;

(b) 1925--Colorado re-ratified the Compact and waived the seven-state requirement (Colorado S.L. 1925, p. 525);

(c) 1928--Boulder Canyon Project Act gave Congressional approval to the Compact subject to conditions precedent (43 U.S.C. 617 c) concerning alternate permissible ratification procedures; and

(d) 1929--California and Utah ratified the Compact, meeting the requirement for six ratifications under the Boulder Canyon Project Act.

--Article III(d) of the Compact, <u>taken alone</u>, suggests that the Upper Division States are absolutely obligated to supply 75,000,000 acre-feet every ten years to the Lower Division States, despite natural deficits.

--The Compact and authorizing Act speak both of Basin and Division States. Article II(c) of the Compact defines "States of the Upper Division" as the States of Colorado, Wyoming, Utah and New Mexico. Article II(f) defines the "Upper Basin" as "those parts of the States of Arizona, Colorado, New Mexico, Utah and Wyoming within and from which waters naturally drain in the Colorado River System above Lee Ferry..." Some of Utah's streams are Upper Basin and some are Lower Basin. The ambiguities of Upper Division and Upper Basin duties under the Compact are magnified for Utah, which is partly Upper Basin, partly Lower Basin and all Upper Division.

The "squeeze" in dividing up the last of the Colorado River is just over the horizon. I would not want to predict the outcome. One can certainly appreciate from the foregoing the predicament of energy companies who must answer for themselves and their clients the question: "Just how sure are you that water is available?" To make matters worse, Article VII of the Compact provides:

> "Nothing in this compact shall be construed as affecting the obligations of the United States of America to Indian tribes."

The ramifications of that disclaimer suggest another and entirely different subject concerning water availability.

Indian and federal reserved rights

A slight different issue of water availability and certainty of supply is presented by the so-called reserved rights or "Winters doctrine."[11] Beginning with the Winters case, courts have found an implied reservation of water from the mere reservation of public lands on the ground that both water and land were necessary to accomplish the purposes of the reservation. The date of the land reservation serves as the appropriation date; most are of very early priority. Five Constitutional bases have been cited by legal scholars for the reserved power:[12] the welfare clause, the war clause, the

[11] See, Winters vs. United States, 207 U.S. 564 (1908) and United States vs. Rio Grande Dam and Irrig. Co., 174 U.S. 670, 702 (1899).

[12] See, e.g., Corker, C. E., "Federal-State Relations in Water Rights Adjudications and Administrations," 17 RMLI 579 (1972): Craig, L.B., "Limiting Federal Reserved Water Rights Through State Controls," Note, Utah L.R. 48 (1972): Guadnola, J.C., "Adjudication of Federal Reserved Water rights," 42 U. Colo. L.R. 161 (1972); Kiechel, W. Jr. and Burke, K.J., "Federal State Relations in Water Resources Adjudication and Administration: Intregration of Reserved Rights with Appropriative Rights," 18 RMMLI 531 (1973): Mills, Lamond R., "Federally Reserved Rights to Underground Water--A Rising Question in the Arid West," Note, Utah L.R. 43 (1973): and Trelease, F.J., "Water Resources in the Public Lands: PLLRC's Solution to the Reservation Doctrine," 6 L&WLR 89 (1970).

commerce clause, the property clause, the treaty clause, plus the additional power of control derived from federally funded projects.

The full impact of the reserved rights doctrine was not felt in western water law until the Pelton Dam case[13] in which the U.S. Supreme Court held that reserved rights could not be impaired by the exercise of subsequent appropriators diverting after the creation of the reservation, i.e., no compensation need be paid to rights called out by exercise of the reservation. That reserved rights to water exist as a result of many varieties of public land reservations was fairly decisively settled in U.S. vs. District Court in and for the County of Eagle, 401 U.S. 520 (1971). Indeed, the doctrine was recently extended to groundwater implied reservations.[14]

Indian reserved rights are of somewhat different character. In their case, Indians had granted vast tracts of nomadic, aboriginal lands to the United States in return for smaller reservations and a settled pattern of existence under special trusteeship. The trust responsibilities of the government toward these Indian tribes and the fact of aboriginal ownership morally, and possibly legally, spell out a different form of "reserved right" than can be claimed for such public land reservations as forests, power sites, monuments, etc. . .

Reserved rights would not cast such a chill into the hearts of appropriators if one could determine with certainty where the rights existed, in what quantities, and with what priority dates. As the situation now stands, however, that type of information is only available after massive adjudications in State and Federal courts. For those of us who must be able to tell our clients, whether they be energy companies or farmers, that a given water supply or right is either valuable or not valuable, reserved rights mean absolute

[13] F.P.C. vs. State of Oregon, 349 U.S. 435 (1955)

[14] United States vs. Cappaert.

uncertainty. The buyer of land can obtain title insurance, but the buyer of a water right gets only the disclaimers of his water attorney. Business thrives best on low-risk enterprises: developing an entirely new industry is risky enough, but the legal and institutional devices which control the availability and the use of water compounds the chances which must be taken.

The Department of Justice is sponsoring legislation which would provide for the inventorying and quantification of reserved, appropriative and other rights to the use of water by the United States.[15] Without getting into the specifics of the Bill, I would suggest that the primary object of such legislation should be to provide certainty for water investors and equity for present water users.

(2) Water quality impacts

Water quality impacts actually associated with oil shale development can be classified as minimal. Our facility is designed so that no processed water will be returned to streams. The sole water quality impact of plant operations will be slight increases in salinity levels which will result from the process known as "salt concentrating"--the loss of water from the total river system through stream depletions. Unlike agriculture, for instance, oil shale operations will not be "salt-loading." I have previously mentioned that TOSCO is studying the possibility of utilizing natural and man-made salt-loading sources for certain internal uses as a way of further mitigating our small salt-concentrating impact. At this point in time we cannot accurately assess our water quality impacts. We do know, however, that the Colony plant would only result in increasing salinity of the Colorado River at Hoover Dam by 1/60th of one percent. Management tools are available to eliminate the impacts of salinity

[15] A draft bill dated June 20, 1974, is presently before the Water Resources Council for review and has not yet been introduced into Congress.

problems. I would call your attention to the proceedings of the 15th Annual Western Resources Conference on Salinity in Water Resources[16] Assistance from the Federal Government is on the way in the form of Public Law 93-320, "Colorado River Basin Salinity Control Act,"[17] which provides for research and development funds as well as a series of desalinization plants.

The other water quality impacts which can be expected to result from oil shale development will be domestic waste water discharges in communities housing the workers. The Federal Water Pollution Control Act Amendments of 1972[18] provide a mixture of effluent controls and funding subsidies to ensure proper treatment of domestic wastes consistent with state-established water quality standards. We have made every effort to assist local communities to plan for provide necessary public services in affected communities in Colorado. It is our intention to do the same in Utah.

Approaches to Water Resource Issues

I would not like to leave this conference without suggesting some approaches which might be useful for integrating an expanding energy industry into Western water resource uses. Each approach must be carefully evaluated for social, economic, and environmental consequences--as long as we all agree that our ultimate goal is action rather than just evaluation.

(1) Water and oil shale inevitably bring one's focus to the White River where there are no present storage projects. It would

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[16] Flack, J. E. and Howe, C. W., Salinity in Water Resources, Merriman Publishers, 1974. See, also, Kleinman, A. P., Barney, G. J., and Titmus, S. G., Economic Impacts of Changes in Salinity Levels of the Colorado River, U.S. Department of the Interior, Bureau of Reclamation, February, 1974 as well as U.S. Bureau of Reclamation Progress Report No. 7, Quality of Water: Colorado River Basin, January, 1975.

[17] 43 U.S.C. 1571 et seq.

[18] 33 U.S.C. 1251 et seq.

appear desirable to have a program designed to develop a single, well-planned, multiple-use, storage project with an inter-state compact between Colorado and Utah concerning an equitable division of the benefits of the project.

(2) The public interest will be benefited by a negotiated agreement on legislation to clarify the reserved rights doctrine rather than protracted litigation or virtual destruction of the present system of state water laws.

(3) As beneficiaries of a large part of the energy to be produced by Upper Basin water, the Lower Basin may have to reconsider some of their claims to Compact water.

(4) State water laws must be re-examined to ensure flexibility to meet new demands on water resources. Incentives toward water salvaging and harvesting techniques should be encouraged. Above all else, reforms should strive to decrease the insecurity of a water right holders and increase the insecurity of speculators.

(5) Controlled experimentation with weather modification and augmentation programs should be encouraged.

WATER QUALITY MANAGEMENT BY THE BLM ON NATIONAL RESOURCE LANDS IN UTAH

by

Donald A. Duff*

Introduction

The environmental effects of water projects and water use are receiving increasing attention in the press, in Congress, and in the courts (2). Stream channelization, agricultural demands, flood control, and major industrial water uses for power plants and energy development projects are but a few examples of water uses that occur on public lands, especially those administered by the U.S. Bureau of Land Management (BLM) in the West.

As an agency of the U.S. Department of the Interior, the BLM has the responsibility of managing a considerable portion of the nation's renewable and nonrenewable resources. This is significant since the BLM manages about 450 million acres of national resource lands, including Alaska, with an estimated surface runoff of approximately 6 million acre-feet per year. Utah is one of four western states in which the federal government administers over 60 percent of the land mass. In Utah's case, 73 percent of the land is in federal ownership, with the BLM managing about 43 percent of the land or 22 million acres. It is estimated that runoff totals about 332 thousand acre-feet per year on national resource lands in Utah (4).

Water resources, both quantity and quality, are a key factor in the management of all resources, both terrestrial and aquatic, on national resource lands, and is rapidly becoming a major determinant in the assessment of resource management alternatives, particularly those

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associated with energy developments. It is worthwhile to note that BLM in Utah manages riparian habitats associated with some 2,000 miles of streams, and 15,000 acres of lakes, reservoirs, or ponds. While many of these water bodies contain unsuitable habitats for a game fishery, some are quality fishing waters, with a few stream miles classified as a "Blue Ribbon Fishery" by the Utah State Division of Wildlife Resources, and all contain water resources, the quality of which provides a beneficial downstream use, whether it is for human consumption, fish and wildlife, or recreation-aesthetics.

I have used these figures to give you some idea as to the magnitude of the water resources and potential management problems on national resource lands administered by the BLM in Utah. With this in mind, let us look at BLM's role in water quality management, past, present, and future, and define areas of problem management which we foresee developing in the near future as a result of increased emphasis on energy developments. I will try to summarize by showing a few representative slides of our activities and problem areas.

Water Quality Management

Water quality management on national resource lands in Utah was delegated a rather low priority for accomplishment by BLM until about two years ago. Up until that time, water resource inventories and quality analysis were conducted rather sparsely, and then only on important waters identified within our planning system. Most water resource data was supplied to us via the U.S. Geological Survey from permanent and temporary gaging stations. While one-time samples, or grab samples, were collected on some waters as the need arose, most perennial waters on small streams (those with a minimum summer low flow of less than 5 cubic feet per second) were deemed rather insignificant by state and federal agencies. As a result, most of these waters had little, if any, baseline inventory data relative to water quality and quantity, fisheries or habitat components.

The need to obtain the necessary baseline water resources inventory data for planning and management responsibilities led us to take a second look at water quality requirements. Internal discussions on this subject pointed out that water quality monitoring was not a new program within BLM, but a very real, existing one. While somewhat neglected in the past, collections of water resources and quality data now are a must for all our resource programs. Water quality relationships exist with all our on-going programs, especially as related to soil and watersheds, energy and minerals, wildlife habitat, grazing systems, and recreation programs.

In what ways are we actively engaged in water quality work at present? We are coordinating with state, federal, and private agencies in the development and implementation of a viable water quality monitoring program for waters on national resource lands within our eight district office areas.

The need for inventory data for the Westwide Water Study led us to initiate a survey of consumptive water requirements for the various natural resource operations on national resource lands (3). Individual resource areas within each of our districts were evaluated in terms of activities and acre-feet of water needed for their operation. Consideration was given to the nonconsumptive water needs for fisheries, wildlife, recreation, and water quality. This baseline inventory was completed in March 1974, and forms a part of the Western U. S. Water Plan Working Document.

We are still engaged in obtaining water quality and minimum flow data on all aquatic habitats now as part of our aquatic habitat surveys. These data are actively utilized in our basic planning documents, as well as in Environmental Impact Reports and Statements.

The recent demand for energy exploration and development has increased our awareness for quality water resource data. Water resources flowing through national resources lands are playing a significant role in the exploration and development of energy resources, such as coal, oil shale, oil and gas, bituminous sands, and geothermal steam. The need for active pre- and post-water monitoring programs to establish water quality characteristics at project sites has been shown to be beneficial time and again throughout the nation to assess environment impacts associated with a project to provide for protection of the downstream water and habitat resources.

The Federal Water Pollution Control Act and Executive Order 11752 specifies that any federal agency responsible for an activity which may result in the discharge or runoff of pollutants shall comply with federal, state, and local requirements respecting control and abatement of pollution to the same extent that any person is subject to such requirements. We have taken immediate action to comply with these laws, especially in energy development areas.

In the White River oil shale area, in northeastern Utah, where the two 5,000 acre lease tracts are located, the BLM began to monitor water quality on a scheduled basis one year before leasing in cooperation with the Utah State Division of Health, and the U. S. Geological Survey. As a part of the lease stipulations on these oil shale tracts, it is specified that baseline resource data, including water quality, be monitored for a two-year period prior to any development. Because of the value of water resources and their use in monitoring the environmental impacts of energy developments, this requirement for two years' baseline data on water quality may become a standard stipulation in the leases for significant environmental actions, such as oil shale, coal, and bituminous sand tracts, as well as major power plant developments.

As part of the Bureau's Energy Minerals Resource Inventory Analysis (EMRIA) program, the BLM is cooperating with the U.S. Geological Survey in an intensive hydrologic study in the potential oil shale development area encompassing 3,000 square miles within the Uinta Basin of east central Utah. Water quality sampling will be conducted at a total of 31 sites, including both partial and continuous recording stations within this area.

Also included in the EMRIA program is hydrologic data collection in potential coal development areas. Water quality measurements include physical, chemical, and radiological constituents of surface and groundwaters. In order to determine the reclamation potential of representative coal lands after mining, and to specifically estimate the effects on the local hydrologic system from coal mining and the reclamation of land after mining has been completed, the Bureau selected four pilot areas for study in known coal fields. In Utah, a 2,600 acre tract has been selected in the Alton Coal Field, northeast of Kanab, Utah. This study area is within a 27,000 acre tract of strippable coal presently under lease for development. The U.S. Geological Survey and the Bureau of Reclamation are cooperating with the BLM in the soil, water, vegetative, and mineral studies within this area.

A total of about 27,000 square miles of color infrared aerial photography was flown in 1974 in the potential oil shale and coal development areas to aid us in field investigations and study. Approximately 12,000 square miles are scheduled to be flown in 1975 with color infrared aerial photography.

While all land management activities have and probably will continue to have some impact, although minimized, on the water quality resources, the most significant and subtle impact degrading water quality is from the domestic grazing of animals. The elimination of riparian vegetation causing stream bank deterioration and erosion have significantly degraded water quality values on the site as well as in downstream areas. The biological productivity of some stream areas has been affected and, in many cases, greatly reduced, through continued grazing uses. The BLM has and is continuing to evaluate grazing systems and make adjustments in use for the protection, enhancement, and management of riparian habitat areas. In some test cases, total exclusion of grazing has been implemented in areas where either quality habitat exists, threatened or endangered species occur, or inadequate vegetative composition occurs to sustain grazing uses.

While multiple-use management systems appear to be best for the resources in theory, actual applications of such use can be detrimental to an ecosystem if a series of checks and balances, or alternatives, are not built into the system. Dr. A. Starker Leopold, University of California, Berkeley, in an address titled "Ecosystem Deterioration Under Multiple Use," given at the Wild Trout Management Symposium in Yellowstone National Park in 1974, stressed the impacts of livestock grazing to the aquatic exosystem, and challenged resource managers to evaluate the problem and take action, where necessary, for the benefit of all land and water resources (1).

The BLM has been conducting water quality surveys on waters specifically oriented to grazing use where deteriorating conditions are known to exist. These studies will be continued and expanded in 1975. It is hoped the use of water quality data along with physical habitat, and biological data, especially stream macroinvertebrate fauna, will provide the needed information on which to base sound management decisions to arrest the decline of aquatic ecosystems.

Another area the BLM has been active in during 1974 has been the Colorado River Salinity Control Program. Contract studies to state and federal agencies are providing us the needed information for soil and watershed management. Utah State University is providing us with information on the effects of land uses on salts movements for selected land and vegetative types in the Price River Basin. The Bureau of Reclamation is preparing maps for us outlining soil, salinity, and vegetative characteristics in the Upper Colorado River Basin, while the U.S. Geological Survey is providing us with data and analysis on water quality-salinity relationships within the San Rafael River Basin and the Pariette Wash area.

What does the future hold for the BLM in water quality management? We plan to increase emphasis in water quality monitoring on natural resource lands in cooperation with federal, state, and local water agencies. Technological advances in computer sciences and water quality monitoring, such as a remote sensing data collection platform used in conjunction with a satellite, will greatly enhance our capability to identify problems to protect water quality and values in energy development areas, particularly oil shale and coal lease tracts.

We are hopeful of passage of an Organic Act by the Congress which will give BLM management and enforcement authorities to adequately manage its resources for the American public. As it is now, BLM responsibilities and authorities derive from an assemblage of about 3,000 laws and regulations, some of which are vague and hinder the management of land and water resources.

If I may summarize several points that I mentioned earlier, we are beset by a number of increasing demands on the use of water resources, chiefly from energy developments, as well as our on-going programs in recreation, grazing, and watershed management.

The following examples will serve to illustrate some of the problems associated with these demands. Energy exploration, such as oil drilling activities can cause environmental impacts on water quality. Here wastewater from core drilling results in surface erosion, and residues of drilling mud when the water evaporates. Wastewater ponds and springs created as a result of core drilling, and not properly cared for, can cause death from water contamination for livestock and wildlife. Oil spills are becoming more frequent and can cause significant destruction to the aquatic ecosystem on small, but important, streams on national resource lands. Burning is one efficient means of cleaning up oil spills, but it is aesthetically displeasing and it also leads to increased erosion and sedimentation into waters from resulting unstabilized soil conditions.

Coal mining activities and resulting waste piles adjacent to stream courses cause degradation of water quality, and in smaller streams like this, the elimination of its biotic productivity. Water and wastes from gilsonite mines can have similar impacts on the aquatic ecosystem.

Increased recreational use of major waterways for floatboat use increases the likelihood of pollution on many remote waters previously unused by visitors. Fishing and water-related activities on water bodies without adequate sanitation facilities and campgrounds are causing increased pollution and management headaches for the BLM manager. The most subtle impact on water quality is occurring from domestic grazing animals, particularly livestock. The elimination of riparian vegetation, bank trampling, and the resulting erosion is causing on-site as well as downstream water quality degradation.

We estimate that about 70 percent of the aquatic habitats, and associated water qualities, are in unsatisfactory condition on national resource lands in Utah. However, with adequate planning and on-the-ground surveys and management, the BLM is providing for the protection and enhancement of water quality resources for the public's future use.

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ENERGY DEVELOPMENT AND WATER RIGHTS

by

Dallin W. Jensen*

Because of the accelerated interest in the development of Utah's natural resources in the Colorado River Basin, potential developers are--with increasing frequency--asking the State Engineer if there is unappropriated water available for this purpose. These potential water users are frequently surprised to find that Utah is approaching a total allocation of its share of the Colorado River System. This is puzzling to those not familiar with Utah's rights from this water source because they see the large quantities of unused water available in the various river systems in the Colorado River Basin in Utah and therefore suppose there is ample water for numerous additional uses. Of course, what many potential users fail to understand is that Utah's rights to this water are limited not only by the physical availability of the water itself, but also by interstate compacts and a treaty between the United States and the Republic of Mexico. Therefore, any discussion of Utah's water resources in this basin must begin with an understanding of these documents. All water rights acquired from the Colorado River System in Utah, as in the other Upper Colorado River Basin States, must be related to and measured against the compact rights of the states.

The Colorado River Compact of 1922 fixed the obligations between the Upper Basin and the Lower Basin, and while this agreement did not allocate specific blocks of water to the states, it did have the effect of allocating the Colorado River between the two basins, with Lee's Ferry as the division point. Based on historic flows, the negotiators of this compact anticipated that each basin would receive approximately 7.5 million acre-feet of water per year. However, nature has not produced

*State Engineer's Office.

the quantities of water which the negotiators contemplated, and the Bureau of Reclamation now estimates that the Upper Basin entitlement is in the neighborhood of 5.8 million acre-feet annually. (The Utah Division of Water Resources' estimate is somewhat higher.) Subsequent to the 1922 Compact, the Upper Basin States reached an accord on the division of water between themselves, and in 1948 finalized the Upper Colorado River Basin Compact. This latter compact, except for the allocation of 50,000 acre-feet of water to the State of Arizona, apportioned the water among the Upper Basin States on a percentage basis, with Colorado receiving 51.75 percent, New Mexico 11.25 percent, Utah 23 percent, and Wyoming 14 percent. In addition to these compacts, the Mexican Treaty places an obligation on the Colorado River of 1.5 million acre-feet annually. And, while there is some dispute between the Upper and Lower Basins as to how this obligation is to be satisfied, it is clear that it is a prior demand on Colorado River waters.

Thus, while the 1948 Compact accomplished a general allocation of water among the Upper Colorado River Basin States, there still remains the problem of evaluating each state's apportionment in terms of specific interstate streams. This is so because, except in a few instances, the Upper Colorado River Basin Compact did not apportion water from specific streams. One of the interstate rivers which is causing a great deal of interest at the present time is the White River. This river flows from Colorado into eastern Utah and is in the vicinity of some of the richest oil shale deposits in the two states. Historically, this river has delivered approximately 500,000 acre-feet annually at the Utah border. Utah and Colorado are now involved in preliminary discussions in an effort to determine the equitable share of each from this source. Of course, it must be remembered that the ultimate use from this and other tributaries will be limited by the states' total compact allocation. Thus, the concern facing each of the states is to relate their total allocation to the specific uses which exist in the state and to make some determination where they intend to use their remaining allocation.

Turning to the more specific question of what Utah has done with its Colorado River entitlement, approximately one-half of our Colorado River water has been placed to use. The Utah Division of Water Resources estimates that the current existing depletions from the Colorado River Basin in Utah are approximately 700,000 acre-feet and estimates that Utah's total allotment based on current water studies would be about 1.4 million acre-feet. This would leave approximately 700,000 acre-feet of water from Utah's allocation which is not currently being used. But it is misleading to suggest that this water is available for new appropriations. This is so because the State Engineer estimates that he has approved sufficient additional applications to deplete the Colorado River System another 600,000 acre-feet. This figure includes the filings which have been approved for the various phases of the Central Utah Project. In addition to these approved filings, there have been filed a number of other applications to appropriate water which have not been acted upon by the State Engineer. While no definitive tabulation has been made of the quantity of water encompassed by this group of filings, it is estimated that they would total a quantity of water sufficient to take Utah way over its compact allocation.

This brings us to one of the State Engineer's problems. He feels that applicants holding approved applications should be required to proceed with greater diligence to place the water to use and if this cannot be accomplished in a reasonable time the application should be lapsed and a new applicant given an opportunity to develop the water. As most of you know, under Utah law once an application is approved the applicant must proceed with due diligence to divert the water, place it to beneficial use, and submit proof of appropriation. Otherwise, his application may be lapsed. However, the standard against which due diligence has been measured is somewhat lax. Consequently, legislation has been introduced into the current legislative session to require all applicants to affirmatively show that they are exercising reasonable and due diligence toward completion of the appropriation. (This legislation was passed and has been signed by the Governor, see S. B. #290, Laws of Utah, 1975 Regular Session.) It is believed that this amendment will provide sufficient additional authority to the State Engineer to lapse old approved applications where the applicant has failed to take steps to place the water to use. The water covered by any lapsed application would be available for reallocation.

The problem of allocating Utah's unappropriated water was the subject of another recent legislative bill, S. B. #291. Under Utah's present statutory appropriation scheme, the State Engineer has traditionally approved applications based upon the priority in which they were filed. Thus, the first applicant to reach the Engineer's Office would be the one whose filing would be approved, even though a subsequent application may propose a better project and be more in the public interest. The State Engineer believes that this statutory scheme should be modified to allow the approved applications in the public interest, rather than being based upon the date when the application was filed. If this type of legislation is enacted, the State Engineer would be able to approve an application for an oil shale company, for example, even though it was filed in 1975, and allow that company to proceed with the development of this energy resource if he determined that the application was in the public interest. Thus, he would be able to select those unapproved applications which would better serve the public interest without regard to the date the application was filed. Under this proposal, the State Engineer would consider all relevant aspects of the public interest, and:

> In so doing, he shall give fair consideration to: (1) the public interest aspects and impacts of the economic, social, recreational and environmental values resulting from the proposed use; (2) the benefits to the applicant resulting from the proposed use of water; (3) the benefits to the State, region, and locality resulting directly or indirectly from the economic activity that will result from the proposed appropriation and use of water; (4) alternative future uses of the water sought to be appropriated; and (5) alternative sources of water to satisfy the applicant's needs. After considering, weighing and balancing the various elements of the public interest as

above defined, the State Engineer shall approve the application if it is in the general public interest, and shall deny the application if it is not. Provided however, that the State Engineer shall not be required to approve or reject applications in the order of their respective priorities whether filed before or after the effective date of this act.

This legislation also provided that the State Engineer could approve applications for commercial, industrial, power, mining development, or manufacturing purposes for a limited or fixed period of time. The elements of this legislation would certainly seem to provide a better procedure for the allocation of the state's water resources. Unfortunately, this legislation was defeated, but it is anticipated that it will be reintroduced at the upcoming Special Session of the Utah Legislature in June.

While the foregoing discussion is centered around applications to appropriate as a means of acquiring water for energy development, I don't mean to suggest that this is the only method of acquiring water for energy projects. Time will not permit a review of alternative methods of acquiring water rights for such projects, but a few alternatives should be noted for those who may wish to investigate them further. Under Utah law it is possible to purchase existing rights and change these rights to accomodate new development. It is necessary to file a Change Application with the State Engineer and secure his approval before such a change in point of diversion, place, or nature of use can be accomplished. The Utah law governing changes is designed to provide the maximum flexibility in making such changes, and a change is entitled to approval by the State Engineer if these is no enlargement of the basic right and if other rights are not interfered with by the proposed change.

Another avenue which a potential developer may wish to explore involves public water supply districts. For example, in the Uinta Basin there exists the Uintah Basin Water Conservancy District and the Central Utah Water Conservancy District. Both these districts exist for the purpose of developing and providing water supplies for their inhabitants, and both are involved with the construction of various phases of the

Central Utah Project. Thus, these districts should be able to provide a water supply to accomplish the development of our energy resources. Also, the Bureau of Reclamation holds approved applications in connection with various phases of the Central Utah Project. Thus, the Bureau has approved water filings which could supply water for energy development. The foregoing is simply a very brief synopsis of some alternative means of acquiring a water supply. If these are of interest to any of you, I would suggest that you inquire directly to the agencies involved for additional information.

There is one additional item which should be noted with respect to future water supply in the Uinta Basin. As most of you know, the Ute Indian Tribe has reservation lands in this area. Under the pronouncements of the United States Supreme Court, they are entitled to sufficient water to irrigate all of the irrigable acreage within the reservation. In other words, the Indians would be entitled to a water right to irrigate all of those lands susceptible of being irrigated. In recent years, certain tribes have taken the position that they not only have rights for irrigation, but are also entitled to industrial water rights to develop all of the industrial resources which may be located on their reservation. Perhaps the potential problem this poses can be best demonstrated by a specific example. The White River flows through the Uintah-Ouray Indian Reservation which contains oil shale deposits. If the Indian claim to an industrial water right is valid, this could mean that the Indians would have a substantial block of water over and above their irrigation rights. Consequently, the quantity of water available for other uses in this area would be substantially reduced. I am not aware of any state which is yet willing to acknowledge that the Indian claim is this comprehensive. However, I am advised that there is litigation in the federal court system to test this issue, and I would expect that in the not-too-distant future there will be a legal pronouncement on this matter. My only purpose for noting this today is to advise you that the problem does exist and that it could have an impact upon the future development of Utah's water resources.

SOME ECONOMIC IMPLICATIONS OF PROJECTED WATER-ENERGY PATTERNS IN THE COLORADO RIVER BASIN

by

John E. Keith, Jay C. Andersen, and B. D. Gardner*

Introduction

Energy production in the Upper Colorado Basin is expected to evolve in three directions. These are: (1) oil shale and other petroleum mining and refining, (2) coal mining, liquefaction, and gasification, and (3) fossil fuel and nuclear fired electrical power generation. Each of these activities is expected to affect the quantity and quality of water in the basin. In turn, economic activity in both upper and lower basins is expected to change. In this paper we attempt to identify some economic changes that might be expected in association with large-scale energy development.

Economic Problems

We shall comment on four broad kinds of economic problems expected to arise as a result of large scale energy development. The first is the change in the allocation of water and its impact on the regional economy; the second is the alteration in the array of external effects which will confront downstream users; the third is the distribution of benefits and costs of the development (that is, the equity problem); and the fourth is the selection among options for coping with water quality problems. To some extent, these problems resist compartmentalization.

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For instance, the characteristics of the external effects relate closely to the appropriate control mechanisms and to the distribution of benefits and costs.

Quantity of water

The reallocation of water between current uses and energy development will depend on the existence or development of transfer mechanisms. Since water-right allocations already exceed current water production, questions of trade-off values among uses become critical.

Some estimated water requirements projected for energy production in the Colorado River Basin in 1985 are presented below in Table 1 (Water Resource Council, 1974):

Table 1. Consumptive use of water for energy.

	Annual Use 1,000 acre ft/yr
Coal Gasification	200-900
Coal Liquefaction	100-650
Coal Fired Electrical Gen.	300-400
Oil Shale	100-200
Coal Pipelines	30-60
Coal Mining	14-23
Nuclear Power	10-20
Oil Refining	6-12
Total	700-2300

These estimates emphasize that a significant proportion of the available Colorado River water may be used for energy production in as few as ten years if the development occurs as projected.

It definitely appears that the value of water in the anticipated energy-related uses will substantially exceed its value in current ag- cultural uses, and that these new uses have a much more inelastic demand for water. The table below shows a computation of the percent increase in the cost of energy products if the developers had to pay $200 per acre foot for water compared to obtaining it free.

Table 2. Increase in costs of production for energy products. (J. Clair Batty, Unpublished Data, Utah State University, Logan, Utah, February 1975).

Water Use	Cost increases for a $200 per acre ft increase in price of water
Coal Gasification	2%-8%
Coal Liquefaction	1%-6%
Coal Fired Electrical Gen.	1%-2%
Shale Oil	0.6%-1%
Coal Pipelines	2%-3%
Coal Mining	0%

By comparison, agriculture might experience an increase in total costs of approximately 400 percent as a result of the assumed $200/acre foot water cost. Agricultural water is estimated to have a maximum value of about $25/acre foot (Anderson et al., 1973). Further, munici- pal users have seldom had to pay more than $100 per acre foot for other than culinary purposes. Clearly, there will be an impetus to transfer water rights from irrigation to energy uses.

It can easily be seen that a diminution of agricultural activity based on gravity flow irrigation is to be expected. Actual reductions in acreage and production are difficult to estimate, since return flows to the river from energy users will be larger than those from agriculture for a given diversion. Since water rights are generally stated in terms of diversions, not consumptive use, water rights in excess of the indicated 700,000 acre feet would be projected as having to be purchased for energy production. Approximately 1,500,000 acre feet of diversion may be necessary for the cooling operations of energy alone (WRC, 1974). If the current water right allocation is maintained (that is, no adjustment is made for energy's lower consumptive use of diversions in once-through cooling), then at least 150,000 and perhaps as many as 400,000 acres are likely to go out of agricultural production. This is a significant portion of the Upper Basin's 1,600,000 acres, of which 1,300,000 lie in the energy-rich Green River and Upper Main Subbasins. On the other hand, if the energy return flows are reallocated, about half the projected acreage reduction might occur. In either case, agriculture can be expected to decline in regional economic importance as a result of energy development.

A growing energy sector will also bring community problems in supplying health services, law enforcement, domestic water supplies, educational facilities, and other local services and amenities. Rapid growth in a community may put severe economic and social stresses on current and future rural community residents.

The process of changing water use from agriculture to industry may also distinctly change the quantity and quality of river water. The effects of such changes on downstream users may also be substantial although difficult to assess.

Water quality

We lack clear evidence of the effects that water quality and quantity exert on diverse types of economic development. Nevertheless, certain damages to current agricultural, municipal, and industrial users can be

[1]Assuming once-through cooling, energy consumptive use takes between 30 and 40 percent of diversions, leaving 60 percent as return flows. Agricultural consumptive use rates range from 50 to 60 percent in the Colorado Basin.

and have been estimated. For many industries, however, water costs and water quality improvement costs are small and their demands are relatively unimportant in their location decisions. Rapidly growing metropolitan areas have sprung up in areas of water scarcity and/or relatively poor quality water, proving that water may not be the most critical factor in development decisions. On the other hand, certain types of development seem to require an abundance of good quality water. Projections of economic activity as constrained by water availability and acceptable quality are, therefore, subject to wide margins of error.

External effects

Many production processes that are heavy users of water, including those in agriculture and energy, produce external effects (externalities) on other water users along a water course. The externalities which are now being or are likely to be produced occur primarily in the form of degradation of water quality, both by pollutant loading and consumptive use which increases the pollutant concentration in the available water. Since the Colorado Basin has substantial natural salt and sediment loading, consumptive use which concentrates both salinity and sediment is of particular importance. These externalities, created by upstream users, become costs which must be borne by downstream users.

The "external effects" issue can be described diagrammatically (Figure 1). Assume optimal irrigation technology, cropping patterns, and technical production conditions as seen from the viewpoint of the irrigator. (What is optimal for the irrigator may not be so for society if external effects exist.) Subtracting variable production costs from crop revenues will yield marginal net benefits to agriculture (MNB) in Figure 1. The function MNB is negatively sloped because of the conventional principle of diminishing marginal returns to increasing quantities of water, assuming adequate water supplies and optimal deliveries over the irrigation season. The relationship is presented as linear, but the logic of the analysis holds regardless of the exact shape of the function, so long as it has negative slope.

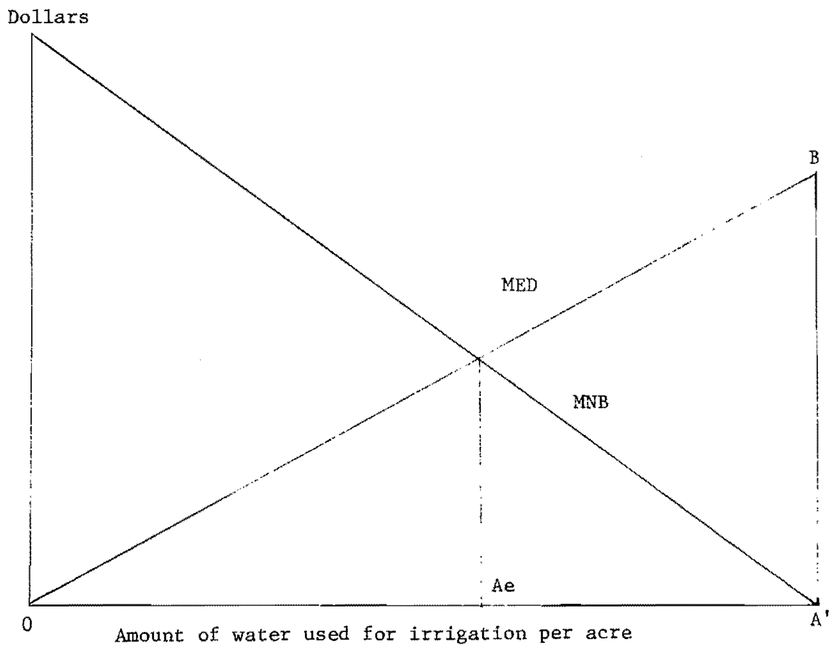

Figure 1. Marginal damages and benefits of utilizing irrigation water.

MED in Figure 1 represents a schedule of marginal external damages inflicted on downstream users as increasing quantities of water are diverted upstream. These damages are the external effects which interest us. The extent of such damages is related to two phenomena: (1) Irrigation water consumptively used upstream cannot be available to downstream users, and the concentrating effects in the river downstream will be directly related to upstream consumptive use; and (2) the saline return flows increase the salt loading, which imposes additional higher production costs on downstream users. Therefore, the greater the upstream diversions the greater the damages imposed downstream, ceteris paribus. The MED function may not always be linear as presented, but a necessary condition to the argument is that it have positive slope.

MED do not normally enter the decision framework of an upstream irrigator. If we assume he attempts to maximize his own net benefits, he will extend his water use per acre to AO' where MNB are zero. His total per acre net benefits are illustrated by the area under the MNB curve, which is maximized at OA' units of water utilized. This may be referred to as his private water "rent." The marginal external damages at that level of use are A' B. Clearly, this level of water use is not optimal in terms for the whole river system. Marginal net private benefits are zero, whereas the marginal external damages are not. By restricting water use to one unit below OA', the foregone private benefit will be zero at the margin whereas the reduction of external damages will be A' B at the margin.

The socially-optimum position is OAe, where MED = MNB. At rates of use below OAe, the marginal net benefits accruing to the irrigator exceed the marginal external damages imposed on others, and society benefits from expanding per acre water use. Beyond OAe, the reverse is true.

The conclusion is quite clear. Salt concentrations will exceed the social optimum so long as the irrigator's water right permits him to use more than OAe units of water per acre. Potentially, at least, the river may yield a greater total economic product if the salt inflow and consumptive use upstream is reduced. This can be accomplished in numerous ways. Restricting the quantity of water used to OAe units is one way; shifting the MNB and MED functions to more socially advantageous positions is another. The best way to accomplish such a shift is an institutional as well as an economic problem. Some options could achieve a reduction in concentrating effect at lower economic costs than others, but institutional rules such as the "law of the river" make them politically infeasible.

Quality changes from energy

The following table indicates (qualitatively where loading rates are unknown) the levels of externalities that would probably accompany each type of energy development (FEA, 1974). Obviously, oil shale mining and the processes of coal gasification and liquefaction are the prime loading forces from energy uses.

Table 3. Pollution by type of energy development.

Activity	Pollutant	Amount	Source
Coal Gasification	ΔT	3^{o}	Once-through cooling
	TDS	Moderate	Process
Coal Liquefaction	ΔT	3^{o}	Once-through cooling
	TDS	Moderate	Process
Fossil Fuel-Fired Electrical Generation	ΔT	3^{o}	Once-through cooling
Shale Oil	TDS	2,000 ppm	Ash settling, surface disturbance
Coal Pipeline	None	None	
Nuclear Power	ΔT	3^{o}	Once-through cooling
Oil Refining	ΔT	3^{o}	Once-through cooling
Oil		Potentially large	Spills
TDS		Unknown	Process

While salt loading may be a significant factor in further degradation of the basin's water supply, reductions in loading may be prohibitively costly, since between 60 and 70 percent of the salt loading is a result of natural processes. Further, the additions of salt from energy use may be no more, and could conceivably be much less, than the loading which results from gravity flow irrigation. In such a case, an agricultural production decline due to energy development would result in a lowered salt loading. Such reduction might improve quality of water in the Colorado by several parts per million at Imperial Dam. We emphasize might. The information costs of finding out for sure are likely to be very high. In any case, it is quite clear, as mentioned above, that loading from human activity, whether from irrigated agriculture or energy development, do not present the most severe salt loading problems. They arise from natural, non-point sources.

Any consumptive use of water upstream inevitably increase pollutant concentrations downstream, since less water is available for dilution. In general, agriculture consumptively uses about 50-60 percent of its diversions, while energy consumptively uses 30-40 percent. Once-through cooling of fossil-fuel-fired electrical and coal gasification plants would require about 620,000 acre feet (consumptively), or diversions well in excess of a million acre feet (Water Resource Council, 1974). (The indicated diversion of 600,000 acre feet would seem to be a conservative estimate.) Thus, for each acre-foot of diversion purchased from agriculture, the water available downstream might increase by about 1/10 to 1/3 (assuming no change in water right appropriations).[2]

If current policy trends toward total containment of cooling water persist, however, consumptive use by energy will contribute substantially to pollutant concentration compared to once-through cooling with no re-allocation of return flows. While consumptive use of water in cooling towers will seldom approach 40 percent of diversions, total confinement would ensure no return flow from the diversion. In other words, consumptive use would effectively be 100 percent. Thus, a total containment policy for once-through cooling use would be expected to about double the indicated agricultural consumptive use figures. Return flows would diminish by approximately 600,000 acre feet while little salt reduction compared to once-through cooling would be accomplished. Given natural loading of about 10 million tons, the resultant concentration increase might amount to as much as one to two mg/1/day at Imperial Dam. Such increases would be significant in the Basin. There appears to be at least a prima facia case for reconsideration of the total confinement philosophy.

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[2]Note that this would involve essentially a change in the Colorado River Compact in that higher than required flows would be expected at Lee's Ferry. If increased return flows are re-allocated, that is, if compact minimums are maintained as a result of energy diversions, then quality improvement might not be significant.

Distribution of Benefits and Costs

The equity problems associated with energy development are in part due to the externalities it would generate. If the external costs are not compensated, then a net transfer of wealth from one group to another will take place. Further, energy development may generate other uncompensated wealth transfers between sectors within a region, such as an increase in taxes to all inhabitants of a region to support facilities for immigrants.

Measuring such costs and benefits and their incidence on various areas and groups of people can be problematical. The actual magnitudes of direct benefits and damages are difficult to estimate, but less so than the intangible, secondary, and external effects. These are conceptually troublesome as well as empirically difficult to measure. One of the reasons is that many good and bad aspects are not market allocated and thus have no market values.

It has been estimated that a cost of between $110,000 (EPA, 1974) and $240,000 (Kleinman et al., 1974) is borne by downstream users for each additional mg/l/year of salinity at Imperial Dam in California. Other estimates range from $40,000 to $500,000. Because no standard deviation is available, there is no reliable statistical way to choose between the highest and lowest figures and caution in interpretations is necessary. In any event, downstream costs of energy development may be significant, particularly in the Lower Basin.

Additions to pollutant concentrations substantially increase downstream costs. Alternatively, reductions would mean substantial savings. If the substitution of energy for agriculture should bring about further increases in salinity, benefits and costs must be carefully analyzed.

Costs of environmental degradation may be imposed on upstream users to provide downstream users with power. Some of the upstream users would be compensated by income increases, greater employment opportunities, etc., but others such as recreationists and environmentalists would not be. The lack of data to precisely estimate impacts is evident.[3]

Current Basin inhabitants will find energy development bringing changes in burdens of providing public services, in costs of energy externalities over and above quantity degradation, and in life-style. The magnitude and direction of these changes are guesses at best. The anticipated uncompensated transfers of wealth or welfare are even further from quantification, although some are identifiable. Constraints on quality deterioration could transfer wealth from upper basin users to lower basin users (while no constraints do the opposite). Institutional limitations imposed on energy development would act similarly. Magnitudes of these potential transfers can only be partially foreseen, and even then have large variances. Wealth may also be redistributed within the basin. Relatively poor agriculturalists may lose income as a result of quality constraints, while relatively rich industrial workers and owners may profit.

Options for management

Since the basin contains numerous polluters and numerous receivers, there are few mechanisms by which beneficiaries can directly compensate the damaged. Thus, legal and institutional constraints become the prime tools of management. Implementation of controls, such as effluent taxes, effluent standards, and stream standards which affect upstream activity, should meet efficiency tests, or at least be treated in an efficiency analysis. Several other efficiency questions arise in conjunction with attempts to control salinity. First, can the controls be implemented at relatively low administrative and information costs? Second, will the controls impose external costs on those not

[3]Note, however, that any sale of water rights from agriculture to energy would be a compensated transfer and would constitute an "equitable" re-allocation. If such a sale becomes possible as a result of downstream power purchases from energy developments, then the upstream-downstream transfer may be equitable as well.

subject directly to their constraints? Finally, will the total upstream costs be offset by downstream benefits? Again, data are either scarce and unreliable or nonexistent.

Subsidies to upstream users who install technology and water use practices that may reduce loading and/or consumptive use are subject to similar questions. The subsidy must be sufficient to offset increases in costs and decreases in production, but specific magnitudes are currently not known, nor do we have any estimate of their potential effectiveness. Clearly, economic justification for energy development is no more possible than is an accounting of its probable costs and benefits or its effects on water quality and related human activity in the Colorado Basin.

Yet the development is being implemented and is bringing with it various problems, some of which are noted below. Relevant laws are difficult to enforce because of the classification of entities coming under the laws. For instance, irrigation companies vary greatly in size and function (some are direct flow, some are storage). Farmers may own stock in several companies. If a regulatory law focuses on the area served by an irrigation company--for instance, irrigation companies that service more than 3,000 acres are subject to enforcement--it may be difficult to decide whether a particular parcel comes under the law. While this may be primarily an institutional or legal question, the costs of administration due to such complexities may be very heavy. If the size of livestock and crop enterprises is a criteria for application of the law, people may limit their operations in an inefficient manner, or they may evade the law by juggling ownership units so that actual operating units reflect multiple owner and operator status.

Many of the laws governing water allocation make it difficult to improve water quality. The concept of "beneficial use" does not promote efficient use of water in an economic or physical sense. Nor does it require that advanced technology and good management practices be used. Allocation based on "beneficial use" can increase quality problems since there is no quality dimension in the concept. The doctrine is so well-established, however, that abandonment may be impossible. It may need to be accepted and methods devised for its improvement. Related to this point, in many cases water rights exceed full irrigation requirements. To protect a right which may some day have value in use or for sale, excessive water is applied and water quality suffers because of leaching. The cost of the water may be slight, while the cost of labor and capital to improve the water management is high. Agriculturists have no incentives to reduce water applications or to improve the quality unless they are artificially imposed. But freedom of choice and individual sovereignty in determining use of property have historically been highly esteemed. The imposition of controls to force the internalization of external costs in certain activities thus challenges traditional values.

It is reasonable to assume that the imposition of standards or taxes may in some cases produce losses greater than the benefits of higher quality water, particularly when large, diffuse natural pollution sources are involved. Identifiable polluters may be asked to bear control costs that exceed their actual "share" of the pollution. Further, if possible, identifiable and controllable point sources may be deliberately converted to un-regulatable diffuse sources so that polluters can escape regulation.

Obviously, we have no guaranteed avenue to optimum management of the Colorado. It is even more clear, however, that until sufficient data has been gathered from the entire basin and critically analyzed, management may be inefficient, ineffective, and costly. The need for research is urgent. Private and public agencies should be mounting significant efforts, both in time and funds, to obtain the requisite information and perform the critical analyses.

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SOME POSSIBLE IMPACTS OF ENERGY DEVELOPMENT ON UTAH'S WATER INSTITUTIONS

by

A. Berry Crawford and Gary D. Weatherford*

Introduction

Planned and projected energy developments in Utah will almost certainly accentuate two interrelated problems which already have reached serious proportions. One of these problems is the scarcity of inexpensive water; the other is the high salinity of the water. This paper will identify several institutional issues in this general problem context and will consider how Utah's water institutions might respond to them. To set the stage for this discussion, the paper will first relate planned and projected energy developments to the problems of water scarcity and salinity.

Energy Development and Water Scarcity

Water scarcity

The "scarcity" of water, of course, is relative to demand. In Utah, as well as the other arid states of the Colorado River Basin and the Southwest, water demand exhausts supply. As a general matter, the utility of water is parceled out to regions, states, institutions, and individuals in the form of water rights, which give their owners the right to use beneficially and consumptively a certain quantity of water. Existing surface water supplies available to users in the Colorado River Basin portion of Utah now appear to be almost fully covered by a

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ombination of recognized water rights and applications for water right ertificates. The situation in the eastern part of the state within the olorado River Basin, where the greatest pressures for energy developient exist because of the proximity of coal, illustrates the water scarcity roblem.

In the 1922 Colorado River Compact, the Upper Basin and Lower asin were each given a right to the beneficial consumptive use of 7.5 iillion acre feet (maf) of water annually from the Colorado River system.[1] he negotitators of the Compact assumed, incorrectly, that the average nnual flow of the Colorado River in the future would exceed 16 million cre feet (maf).

Based on the Bureau of Reclamation's 1974 Report on Water for nergy in the Upper Colorado River Basin, the Lake Powell Research roject (LPRP)[2] prepared a series of graphs showing water supply nd projected water use relationships over the next 25 years for each f the Upper Colorado River Basin States and the Upper Basin as a whole. he graph representing these relationships for the whole Upper Basin is rovided in Figure 1.

Several supply assumptions are contained in Figure 1. The "asumed available" figure (6.5 maf) represents the Bureau's scaled-down stimate of the average annual flow (based on measurements taken beveen 1906 and 1973) and a subtraction of the Upper Basin's assumed out disputed)[3] share of the water that must be delivered to Mexico under

[1] See, generally, Meyers, "The Colorado River," 19 Stan. L. Rev. (1966)

[2] The Lake Powell Research Project (LPRP) is a multi-university, nterdisciplinary project which is assessing the impact of man's activities n the greater Lake Powell area. It is sponsored by the Division of Environmental Systems and Resources of RANN (Research Applied to National Needs) in the National Science Foundation. Dr. Gordon Jacoby s the principal hydrologist with LPRP. Figures 1 and 2 were taken from Weatherford and Jacoby, "Impact of Energy Development of the Law of he Colorado River," 15 Nat. Res. J. 171 (January, 1975)

[3] The Upper Basin states dispute that they are obligated to deliver in increment of water as a contribution to the treaty obligation.

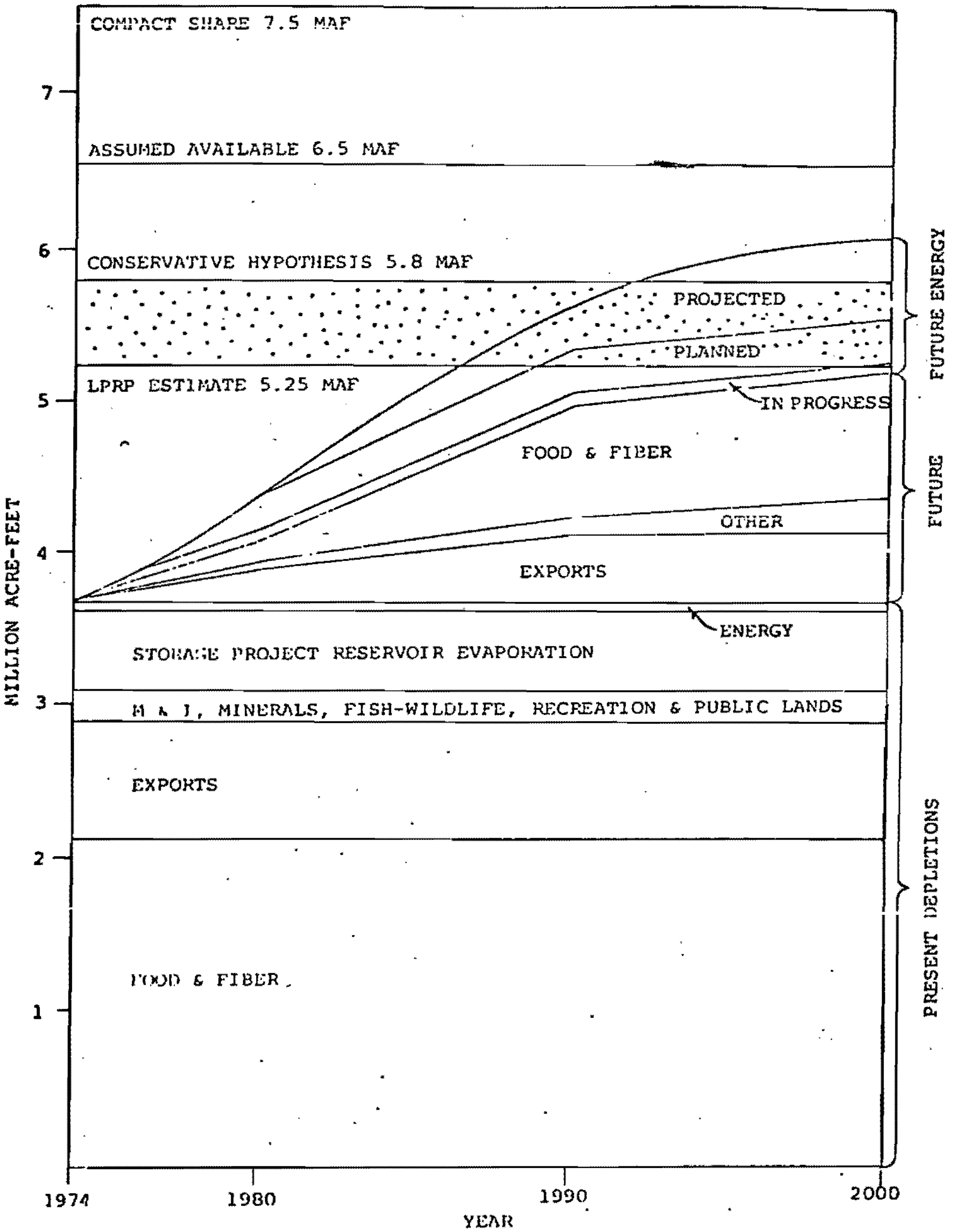

Figure 1. Upper Colorado River Basin, surface water available for consumptive use. Strippled zone represents most likely level of surface-water supply. (Modified after Dept. of Interior, Report on Water for Energy in the Upper Colorado River Basin, 1974.)

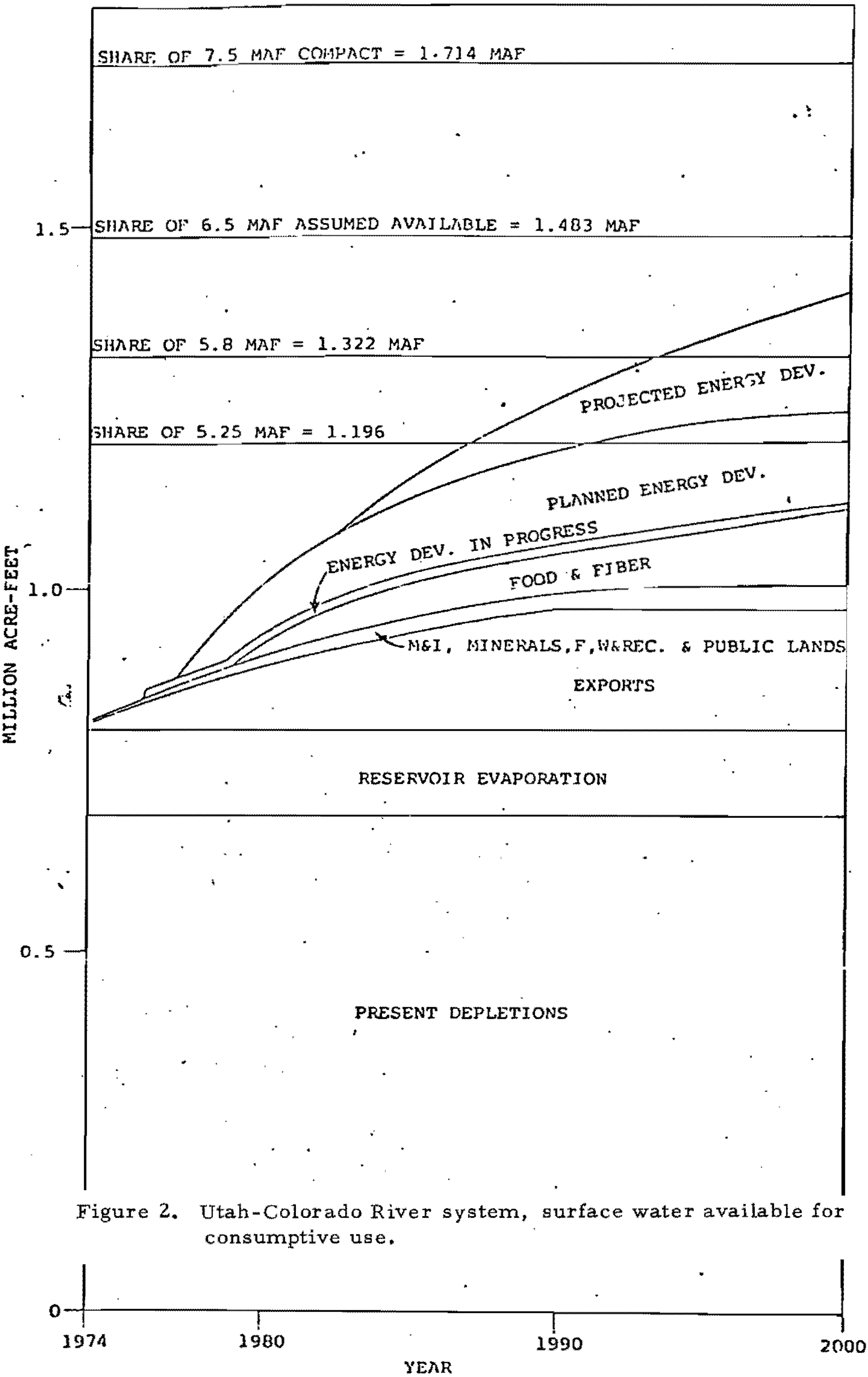

Figure 2. Utah-Colorado River system, surface water available for consumptive use.

the terms of the 1944 Mexican Treaty. The "conservative hypothesis" (5.8 maf) is used as a guide point by the Bureau of Reclamation.

> A Bureau of Reclamation hypothesis indicates that 5.8 maf should be a conservative average amount of water available for consumptive use in the Upper Basin States. Other studies have been made using differing basic assumptions and applying other factors which have suggested both higher and lower annual estimates. Recognizing assumptions upon which the Bureau hypothesis is based, the 5.8 maf will be used as guide point in this report with the recognition that this figure is not supportable by the provisions of the Compacts and the understanding that its use is not intended in any way as an interpretation of the Compacts.[4]

The "LPRP estimate" (5.25 maf) is the Lake Powell Research Project's estimate of available surface water supply in the Upper Basin. It was obtained by using the LPRP's reconstructed 13.5 maf average virgin flow (obtained by correlating tree-ring widths with the Bureau's virgin flows data to extrapolate virgin runoff back to the year 1570)[5] and subtracting both the Compact obligation to the Lower Basin States (averaging approximately 7.5 maf annually) and the Upper Basin's assumed share of the Treaty obligation to Mexico (0.75 maf).

Plotting projected water-use curves against these various supply assumptions, Figure 1 indicates that water use in the Upper Colorado River Basin will exceed the LPRP supply estimate by about the year 1985 and the Bureau's "conservative" estimate in about another seven or eight years, a situation which promises to liven things up institutionally.

With respect to Utah's water supply and demand picture, use of the same supply assumptions[6] in Figure 2 suggests that Utah's

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[4] Dep't. of the Interior, Report on Water for Energy in the Upper Colorado River Basin (1974), at 4.

[5] The results of this study reveal that the early decades of the century were among the wettest in over 400 years.

[6] The 1948 Upper Colorado River Basin Compact allocated the Upper Basin's share of water among the States as follows: Arizona, 50,000af/yr; Colorado, 51.75%; Utah, 23%; Wyoming, 14%; and New Mexico, 11.25%. If the allocable supply of Upper Basin water is 5.8 maf per year, Utah is entitled to 1.322 maf. If the supply is 5.25 maf, Utah's share is 1.196 maf.

consumptive use of water will exceed the Bureau's conservative estimated supply in less than two decades and the LPRP estimate some five or six years before that.

Energy development

The development of extensive coal deposits for energy production and increased extrabasin transfers will comprise the largest increases in consumptive use in Utah.

To the extent that the water needed for energy development in Utah is already used for other purposes, such as agriculture, under existing water rights, the question will become: How, if at all, will water be made available for the emerging energy demand?

The interplay of a number of factors should insure adequate amounts of water for energy development. These factors (discussed in turn below) are: (1) The price of water encourages agricultural appropriators to sell all the water that is needed to energy developers; (2) Utah water law does little to constrain such water rights transfers (although numerous practical problems can delay or discourage transfers); (3) additional water is available from groundwater sources and possibly from Indian tribes holding reserved rights; and (4) Utah's water rights law gives the State Engineer authority to provide additional water as might be needed for energy development.

The current marginal cost of agricultural water -- the cost at which it becomes unprofitable to farm -- is, at maximum, \$25 per acre-foot in Utah.[7] The actual subsidized price of water for Utah agriculture ranges between \$.50 and \$5 per acre-foot. The price of municipal water ranges between \$30 and \$100 per acre-foot. For many agricultural crops, and acre-foot of water priced at \$200 would raise production costs some 600 to 800 percent.[8]

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[7] Anderson, Mark H. et al., "The Demand for Agricultural Water in Utah" (PRWG 100-Y), Utah Water Research Laboratory, 1973.

[8] Personal communication with J. Clair Batty, Utah State University, 1975.

In contrast, if the cost of water were $200 per acre-foot, the production cost increase of coal gasification would be in the neighborhood of 2 to 8 percent; that of coal liquification, 1 to 6 percent, that of coal-fired electrical generation, 1 to 2 percent; that of shale oil, 0.6 to 1 percent; that of coal pipelines, 2 to 3 percent; and that of coal mining 0 percent.[9] Since the price at which agricultural users will find it economically feasible or irresistible to sell their water rights to energy developers will no doubt remain in the range which energy developers can pay, it is reasonable to expect that agricultural water will become available for energy development. Put simply, energy developers can afford to pay and the agricultural appropriators cannot afford not to sell.

Utah water law should offer no serious obstacles to market transfers of water rights. Restrictions against severing water rights from the land, exclusive reliance on a tribunal (rather than an administrative official) to review the engineering and technical economic questions involved in transfers, and various other impediments to the market allocation of water resources which exist elsewhere are not features of Utah's water rights law.

> In a state such as Utah, where most of the water is appropriated, it is generally believed that a realistic and liberal policy on change applications is needed to allow continued development of the state. For example, in many areas of the state new industrial needs can only be met by purchasing existing agricultural rights and changing these old rights to satisfy the new uses. Therefore, a liberal change policy, consistent with protection of other existing rights, is required to meet these new demands. Also such a program will allow for the transfer of less efficient uses to more efficient uses of water. While Utah decisional law on this subject has generally been consistent with this philosophy there are some decisions which seem to narrow the scope of change applications.[10]

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[9] Personal Communication with J. Clair Batty, Utah State University, 1975.

[10] Jensen, Dallin, "Legal and Administrative Aspects of Utah Water Law" in Upper Colorado Comprehensive Framework Study, Appendix III, 1971, at 202-3.

Some caution is in order on this point of transfers, however. Water right transfers can be more complicated in practice than they appear to be in legal theory.

In most instances the transfer will involve a change in the place of diversion and use. It is possible, for example, that a different storage reservoir and water release schedule will be involved in the new use, involving the buyer in contractual arrangements with more parties than simply the seller. Some of the irrigation in eastern Utah, where the greatest impetus for energy development exists, occurs in federally-sponsored reclamation projects in which the delivery of stored and regulated water is a matter of contract. Individual water rights which are dependent upon deliveries under such contracts may not be readily transferable because most of the federal reclamation projects either have not yet been paid out or are subject to rehabilitation loans.[11]

Agricultural water rights can be quite interdependent in practice, with several users being dependent upon the return flows of another user. The vested interests of other water right holders must be taken into account -- either respected or purchased -- in fashioning a workable transfer.

Other potential sources of water are Federal reserved rights and Indian reserved rights.[12] Proceeding on the precedent established by the lease of water by the Ute Tribal Business Committee to the Central Utah Project on a deferred use basis, some energy developers are exploring the possibility of similar arrangements. Use of Lake Powell water in the Navajo Generating Station pursuant to an agreement with the Navajo Tribe is another such precedent.

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[11] See, generally, Meyer and Posner, <u>Toward An Improved Market in Water Resources</u> (National Water Comm'n, 1971).

[12] See, generally, Price, <u>Law and the American Indian</u>, 310-329 (1973); National Water Comm'n, <u>Water Policies for the Future</u> (Chapters 13 and 14, 1973); <u>Winters v. United States</u>, 207 U.S. 564 (1908); and <u>Arizona v. California</u>, 373 U.S. 546, 600-01 (1963).

Some of Utah's energy development, particularly that associated with the development of oil shale and coal-fired power plants, could conceivably be supplied by yet undeveloped groundwater. The amount available and its recoverability, cost, and quality are matters of conjecture at this point, but quantities in excess of a million acre-feet could be involved.

Even if market transfers, reserved rights, and groundwater sources fail to provide adequate supplies of water for energy development, the State Engineer might still act to provide necessary amounts, provided, of course, that his doing so would be consistent with the energy policy of the state. One provision in the Utah code which would enable such action pertains to the right of the state to suspend the right of the public to appropriate surplus and unappropriated waters.[13] Such a suspension was invoked in the 1940's, and continued to the mid-1960's, to preserve waters for the Central Utah Project. For this provision to be meaningful, of course, unappropriated and surplus waters must exist. According to Dallin Jensen in his paper in this same volume, "Utah is Approaching a Total Allocation of its Share of the Colorado River System."[14] He reports that the current depletions from the Colorado River Basin in Utah are approximately 700,00 acre-feet. Assuming that Utah's allotment is about 1.4 maf, this leaves about 700,00 acre-feet which is not currently being used. Of this amount, however, the State Engineer estimates that the exercise of additional approved filings, including those which have been approved for the Central Utah Project, are sufficient to deplete Utah's water from the Colorado River by another 600,00 acre-feet. In addition to the approved but not yet exercised filings, a substantial number of filings are awaiting action by the State Engineer.

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[13] See Wells A. Hutchins and Dallin W. Jensen, The Utah Law of Water Rights, 1965, at 18.

[14] Jensen, Dallin, "Energy Development and Water Rights," paper presented at meetings of the American Water Resources Association; Utah Section, February 20, 1975, Salt Lake City, at 1.

Although no definitive tabulation of these unapproved filings have yet been made, they clearly total an amount in excess of Utah's compact entitlement.

For all intents and purposes, therefore, Utah's share of Colorado River Basin waters has already been appropriated. As a means of giving the State Engineer more flexibility in making future water allocations, the 1975 legislature passed bill S. B. 290 ("Application of Water to Beneficial Use") which requires that applications for extensions of time to put water to beneficial use be considered in light of objective standards for determining whether due diligence has been demonstrated. Personal difficulties or financial limitations will not justify the relaxation of standards. This amendment will provide the State Engineer with authority to lapse old approved applications where the applicant has failed to place the water is use. The water thus "freed" would be available for reallocation. Vigorous enforcement of the "loss of rights through abandonment" provision of Utah's water rights law is also expected.[15]

Another bill was introduced during the 1975 Regular Session of the Legislature (S. B. 291) which proposed that the State Engineer be given the authority (1) to review applications using a public interest standard (as opposed to the traditional "first in time first in right" standard contained in the doctrine of prior appropriation) and (2) to approve applications for commercial, industrial, power, mining development, or manufacturing purposes for a limited or fixed period of time. S. B. 291 was defeated in the 1975 Regular Session, but will be reintroduced in the June Special Session and/or subsequent sessions of the Utah Legislature.

Given these reasons for assuming that adequate amount of water will be available for planned and projected levels of energy development

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[15] Idem, at 3-4

in Utah, then, we need to consider next how recent water quality legislation limits the use of water in energy production and how these limitations might precipitate significant legal and instiutional changes.

Water Quality Limitations on Water Use

Pursuant to the Federal Water Pollution Control Act Amendments of 1972,[16] EPA has issued a regulation[17] requiring the Colorado River Basin States to formulate numeric standards for salinity, consistent with the policy of maintaining salinity in the lower main stem at or below 1972 levels, and to submit a coordinated, basin-wide plan of implementation to EPA not later than October 18, 1975. EPA has also urged that salinity standards be set at state boundaries. The Salinity Forum, comprised of three Governor-appointed representatives from each Colorado River Basin State, was authorized to work with EPA in developing these standards and a compliance plan. Since a 1972-based non-degradation salinity policy was endorsed at the Seventh Enforcement Conference in 1972 and again in the 1974 Colorado River Basin Salinity Control Act,[18] it is expected that the forum will submit and EPA will approve numeric criteria consistent with this non-degradation policy. The drift of discussions between the Forum and EPA representatives at the date of this writing appear to favor the setting of the numeric critera at the international border and selected locations in the Lower Basin, rather than at state boundaries.

The forum's compliance plan will rely heavily on the salinity control projects authorized in Title II of the Salinity Control Act. It will also incorporate the effluent limitations and permit programs of the 1972 Water Pollution Control Act Amendments, as applied to industries, as well as the irrigation source control program

[16] P.L. 92-500; 86 Stat. 816, 33 U.S.C. Sec. 1251.

[17] 39 Fed. Reg. 43721 (December 18, 1974).

[18] P.L. 93-320, 88 Stat. 266.

being developed by the Bureau of Reclamation. The latter includes improvements in on-farm irrigation scheduling, on-farm water management, and water conveyance and distribution systems.

These various pollution control possibilities are all in the early stages of implementation, and it is questionable whether any one of them will be implemented successfully in the future and indeed whether some combination of them will prove to be adequate in keeping salinity at or below the yet-to-be-defined and adopted numeric criteria.

In response to the present EPA policy, most of the waters used in existing or planned energy production facilities will not be returned to the tributary system. The paper by Keith, et al. in this collection takes this policy to task and concludes that total containment is ill-advised in view of the large depletions and high salt concentrations which are involved. However this may be, water use permits and contracts have been and likely will be approved for energy production only if return flows are eliminated.

The real crunch in this whole water quality picture will be felt by irrigated agriculture. The EPA is expected to require return flows to be covered by a discharge permit[19] containing effluent limitations which rely in part on water quality control technology. It is unclear to what extent, if any, the implementation of the effluent limitations will impair the exercise of existing water rights. This is a subject which needs research attention. What is clear is that the increased agricultural costs associated with pollution abatement will be one factor stimulating the transfer of water rights from agriculture to energy.

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[19] A federal court recently struck down the EPA regulations (38 Fed. Reg. 18001, July 5, 1973) which had exempted return floor from less than 3,000 contiguous acres from the permit requirement.

Changes in the concept of reasonable and beneficial use

Enforcement of the Federal Water Pollution Control Act Amendments, particularly the effluent limitation and permit provisions, will in fact limit the use of water. In recognition of this *de facto* limitation, but also to help ensure the enforcement of other control measures lacking the sanction of penalties, various proposals are being made that the beneficial and reasonable use concepts in water law be revised or reinterpreted so as to prescribe the use of advanced technology and management practices in the exercise of water rights.

Traditionally the "beneficial use" and "reasonable use" concepts in Western water law have not required water users to apply the best or most advanced technology. Under common-law (court decisions), methods of water application and management typically are found to be reasonable if they reasonably fit the particular water-use purpose involved, and if they conform with local custom and standards.

In contrast, the Federal Water Pollution Control Act Amendments of 1972 establish technology-based standards for effluent limitation, e.g., by mid-1977 the "best practicable control technology currently available" and by mid-1983 the "best available technology economically achievable."[20]

The stage is set for some conflict between the traditional "beneficial and reasonable use" standard and the new "best technology" statutory standard. Both concepts are probably flexible enough to accommodate over time the dual demands for water utility and water quality, but some litigation and mitigation predictably will

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[20] See Section 301 of P.L. 92-500.

occur in the short run. Specifically, the holders of vested water rights will argue that they have a right to degrade water quality to a reasonable degree and that the governmental imposition of costly control measures amounts to an unconstitutional taking of private property without fair compensation.

It remains to be seen how the interplay between the old and new standards will be resolved in Utah. According to Hutchins and Jensen, The Utah Law of Water Rights (1965), at 45, 53-54:

> The owner of an appropriate has a vested right to the quality as well as the quantity of water which he has beneficially used. This applies, in the opinion of the supreme court, to deteriorations of quality which would materially impair the use to which the appropriator has been putting the water.... The senior appropriator is entitled to protection not only in the quantity of water and the times of receiving it to which he is entitled, but also against such deterioration in quality as would materially impair his use of the water for the purpose for which he appropriated it.

The determination of what constitutes "material" impairment in the exercise of an appropriated right occurs on a case-by-case basis. The amount of degradation permitted by a "beneficial use" is also imprecisely defined under Utah case law. Generally, the application of advanced technology in irrigated agriculture has not been required by the courts.

Pressure has been building in the state for a legislative redefinition of "beneficial use," however, which might variously include the protection of water quality as a beneficial use, require the application of advanced abatement technology and management practices, or otherwise place more explicit water quality limitations on use.

If the concept of beneficial use were revised to include or prescribe the abatement of water quality deterioration, additional costs would be imposed on the water user. This would raise the question "who pays and how?" and might lead to new cost sharing arrangements. It might, for example, provide an effective mechanism for "internalizing" the pollution costs of water use. Significant potential institutional impacts could occur, but a discussion that would do justice to them is beyond the scope of this paper. Suffice it to say that revision of the concept of beneficial use along the lines indicated might conceivably precipitate important changes in the manner in which pollution costs are paid by society.

Salinity control and water resource planning

A second issue area arising in connection with the interface between energy development, scarce water supply, and high salinity is the apparent need for comprehensive water planning, i. e., the need to coordinate and integrate water resources and water quality planning. In this connection, Ronald Robie, Vice-Chairman of the California State Water Resources Control Board, has said:

> ...[T]here is a desparate need to institutionalize the relationship between water pollution and water supply. We know that the two are inextricably interwoven, particularly in states like California where we are moving toward wastewater reclamation and reuse.... Until institutional conflicts are resolved, we are going to have a difficult time effectively managing the entire water resource.[21]

Creation of the Colorado River Basin Salinity Forum represents an attempt at the integration of water resources and water quality planning. The governor-appointed members of the forum represent both water development and water quality officials from the Colorado River Basin states. In Utah, these representatives are the Director of the Bureau of Environmental Health and the Director of the Division of Water Resources. The former, Lynn Thatcher, is the forum's chairman. Given the objectives of formulating numeric salinity standards and a basin-wide compliance plan, consistent with the twin objectives of maintaining salinity in the Lower Basin at or below 1972 levels while at the same time respecting the Upper Basin's right to develop its compact-apportioned waters, the integration of water quantity and water quality planning is an inescapable requirement.

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[21] VII National Resources Lawyer 231, at 237. (Spring, 1974).

Although the experience of Utah's representatives on the Salinity Forum is no doubt conducive to continuing cooperation in intra-state water planning and management, the institutional infrastructure in Utah appears to be lacking. There is no systematic inclusion of the input of the Water Quality Section of the Bureau of Environmental Health, for example, in the approval process for water rights filings. As urged recently by various utilities as a means of shortening lead time, there is also no mechanism for "one stop licensing," i.e., the centralization of regulatory decision-making. Whereas the Division of Water Resources and the State Engineer are in the Department of Natural Resources, and thus are both subject to certain kinds of administrative control, the Water Quality Section of the Bureau of Environmental Health is in the Department of Social Services. The Water Quality Section does have a program thrust in the area of public water supplies, but it is questionable whether interaction in this section of state government has any significant influence on integration at the Division level and whether it influences general water policy. There appear to be few, if any, interactions between the Board of Water Resources and the Water Pollution Control Committee, the policy-making groups for the Division of Water Resources and the Water Quality Section, respectively.

Efficiency, coordination, and centralization are not the only criteria for evaluating the present institutional situation, however. Complexity in American administration reflects, in part, a fundamental preference for splitting up political power and decision-making and for providing institutional support for diverse interests. The existing diversity and complexity reflects the historical evolution of policy. Yet, we wish to pose the question whether existing institutional arrangements within the State are, in the face of the water supply and quality dilemmas which large-scale energy development is thrusting upon Utah, functioning or evolving in such a manner as to make timely and wise responses possible. A brief look at the kinds of water-related planning that are on-going in the state might suggest an answer.

At present, water planning in Utah is performed in three distinct executive agencies: Office of the State Enginer, which is responsible for the administration of the State's water rights law; Division of Water Resources, which administers water conservation and development projects and represents Utah in interstate negotiations involving the state's interstate waters; and Water Quality Section of the Bureau of Environmental Health, which administers the State's Water Quality Act and, as of late, represents Utah's water quality interests in the Colorado River Basin Salinity Forum.

The Division of Water Resources was assigned the task some ten years ago of formulating a state-wide water resources plan. Although still in the development phase, this plan will assess alternative uses for Utah's remaining unappropriated water, and will also deal with the question of how the state can meet its future water needs. Not surprisingly, the State Engineer will play a role in the development as well as the execution of this plan.

Independent of the foregoing planning effort, the Water Quality Section of the Bureau of Environmental Health is developing water quality plans of its own. Several levels of planning are involved. Under Section 106 of the Federal Water Pollution Control Act Amendments, Utah is required to submit to EPA each year a state program plan which outlines the state's principal water quality problems, reviews accomplishments during the previous year, and shows how the state will allocate resources during the ensuing year among the water quality program areas, including planning, the permit system, monitoring and enforcement, facilities construction, training and certification of operators, development of stream standards, public participation, and administration.

A second level of planning is basin-wide planning, an activity that has been on-going for some time. Utah plans to complete basin plans for seven of its rivers by July 1975. These plans provide classifications of each segment of the streams and waste assimilation capacities in relation to the water quality standards established by the state. They analyze future population growth and economic development, and outline systematic management and regulation approaches' for maximizing public benefit with minimum public expenditures. These plans are meant to provide a context or framework for the two other levels of planning, namely area-wide and facilities planning.

Area-wide (or so-called "208") plans will be developed for all areas of the State having serious, area-wide pollution problems. The Uintah Basin is one such area. Among other things, these plans call for the control of non-point sources of pollution, the protection of groundwater, and the regulation of the location and construction of any facilities which may result in pollution. In effect, Section 208 of the Federal Water Pollution Control Act Amendments calls for the integration of land use and water management planning.

Facilities planning, which requires no elaboration here, involves engineering and economic feasibility studies for the construction of wastewater treatment facilities, with the objective of integrating such facilities into basin-wide waste management systems.

Integration of water-resources and land-use planning

A third, closely related institutional issue posed by energy development is the perceived need for the integration of water and land use planning. In its final report, Water Policies for the Future (1973), at 366, the National Water Commission concluded: "Water planning is not adequately integrated with planning for the land uses that water developments are expected to serve." The Commission recommended that if Congress enacted land use planning legislation, it should provide for coordination of water planning and land use planning at all levels of government. As noted above, Section 208 of the Federal Water Pollution Control Act Amendments of 1972 also call for an integrated planning approach.

An effort, known as the "Utah Process" was initiated several years ago in the Office of the State Planning Coordinator, to coordinate all levels of planning the state. In its 1972 report, that office summarized the accomplishments of the Utah Process to that date as follows:

> 1. It proposes and to some degree has systematized, applied, and tested, a structure to implement and maintain a coordinated planning procedure.
>
> 2. It has designed this structure to bring into the planning process the administrators of the various governmental agencies, agency planning specialists, and other decision makers.
>
> 3. It has made use of a planning concept (Alternative Futures) which provides for the continuing consideration of possible future events, singly and in various combinations, which can significantly alter future requirements for governmental services and the order of their priority.
>
> 4. It has evolved a means (Economic and Demographic Impact Model) by which known statistical data, in combination with anticipated but uncertain events, can be projected to obtain a more dependable picture of what the relationship of public needs and available resources will be five or ten years in the future.
>
> 5. It has evolved a planning process which at every step is oriented toward establishing an effective relationship between planning and budgeting.

During the past year, the staff of the Utah Process, in cooperation with the Bureau of Business and Economic Research at the University of Utah, have been developing a land use projection model for translating economic and demographic projections of the Economic and Demographic Model into land use requirements for small areas within multi-county planning districts. Areas within the Uintah Basin have been selected.

Although the "208" planning effort in the Water Quality Section of the Bureau of Environmental Health and the land use planning activities in the Office of the State Planning Coordinator are promising beginnings, it is too early to judge whether they will be successful in integrating land use and water resource planning, or whether these two efforts will have anything to do with each other. It would certainly be premature to claim that the Utah Process has coordinated all levels of planning in the State. Here we find a structure for coordinated planning, but little of the informal kind of interaction and commitment which is necessary to make things work. Within an organizational structure which is seemingly antithetical to coordination, informal interactions do occur, thanks partly to the interactions occurring in the Salinity Forum. In many respects, the problems of the Colorado River Basin are the problems of Utah writ large. Arguably, the Sevier River could be taken as the Colorado River in microcosm.

Conclusion

Change is no stranger to water management. Utah, and the other western states, have seen various economies--mining, agriculture, recreation, energy--and related water uses ebb and flow in strength. The emergent water demand for energy will continue to combine with other forces to precipitate changes in Utah's water institutions. It will be increasingly important to maintain an overview perspective of these changes, one which interprets them in terms of national and regional forces.

A WATER SUPPLY FOR THE ENERGY INDUSTRY

by

J. Bryan Dewell*

This conference has recognized that supplying water for the development of the energy resources of Eastern Utah will be a problem. The traditional problem in Utah has been how to divert sufficient water to the Wasatch Front. These diversions have been responsible for much of the development in the area. However, we now find ourselves in a rather interesting new situation.

Eastern Utah has the resources that would seem to open the door to considerable development. The economies of the communities of Eastern Utah would seem to need the industry. However, the lack of water threatens to limit this development. Utah has heretofore been faced with a problem of how to utilize its share of the flow in the Colorado River. The time is fast approaching when the problem will not be "how can we utilize Utah's share" but rather "how will we allocate Utah's share among the various Utah communities."

The communities of the Wasatch Front will say that they need so much water because their population is projected to be thus-and-so by such-and-so year. Eastern Utah will say that they need the water to develop their resources, their economy needs the industry, and besides they will say the Wastch Front is already overcrowded. Eastern Utah will ask why the development of that region should be sacrificed for the benefit of the Wasatch Front. The problem will be one of allocating our limited water resources among competing uses, not one of utilizing Utah's surplus water. Everyone will want water but there will not be enough to go around.

Is there a way around this apparent dilemma? I think that a solution is at hand. The solution is practical and it is environmentally acceptable.

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It will result in sufficient water for both the continued growth of the Wasatch Front and the development of the energy industry in Eastern Utah. If that sounds good, I have more. This solution to the problem will save millions of dollars.

The solution is this:

1. Supply water for growth on the Wasatch Front by the reuse of municipal water for industrial and agricultural purposes.
2. Utilize Utah's share of the Colorado River in Eastern Utah for the development of the energy industry.

Under this plan much of the proposed expenditures for the Central Utah Project could be avoided along with much of the associated environmental damage. The expenditure for facilities to treat the wastewater does not enter into the economics because the state plans to provide the treatment -- even if the treated water is simply dumped into the Great Salt Lake!

Present plans call for treating municipal wastewater so that it will be suitable for recreation and reuse by 1983. Most highly treated industrial effluents will be too high in salinity for industrial and agricultural reuse. Most agricultural return flows are likewise unsuitable. However, municipal effluents will be completely suitable for agricultural and industrial reuse. This water will be lower in dissolved salts than much present irrigation water. Further, this treated water will contain only 10 mg/l of BOD and suspended solids by 1980 and only 5 mg/l by 1983. The total coliform bacteria count will not exceed 200 per 100 ml by 1980 and the fecal bacterial count will not exceed 200 per 100 ml by that date. Further improvements will be made by 1983.

This may not be meaningful to those not familiar with the terms, but the data show that municipal wastewater of 1980 will be better than many present day irrigation waters of the Wasatch Front.

Why not reuse this treated water? Why not indeed! By 1985 these treated municipal waters will amount to 181,000 acre feet per year.

Such water reuse would release water from planned diversions to the Wasatch Front for use in Eastern Utah. If water is not diverted from the Uinta Basin to the Wasatch Front the planned cross basin diversion would not be needed. Even though some storage would still be needed, the total cost would be much lower than presently planned. Since the water would be transported to its place of use in the natural stream channels, much of the environmental impacts of the Central Utah Project could be avoided. Present plans call for the virtual "dewatering" of several Eastern Utah streams. "Dewatering" is just a nice word for the destruction of a river.

There are several questions that need to be answered before we commit ourselves to further diversion of water from the Uinta Basin to the Wasatch Front. Should we rob Eastern Utah of its water when water is being wastefully utilized on the Wasatch Front? Should we encourage further development on the already overpopulated Wasatch Front or should we provide the water resources necessary for the development of Eastern Utah ? Are we building dams just for the sake of the politically powerful Wasatch Front or will we use our available water resources for the benefit of all of Utah? These questions should be asked and answered.

How we as engineers answer these questions will determine whether we are building for the benefit of our fellow man or just building. People are now asking engineers whether we are part of the solution to today's problems or part of the problem. If we can show our fellow man how to conserve our limited resources then we are certainly part of the solution. If we can only show him how to expend our limited resources faster, then we are part of the problem.

GEOTHERMAL ENERGY AND WATER RESOURCES IN UTAH

by

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We are experiencing a revival of interest in many sources of energy which were not economically viable during an era of abundant low cost fossil fuels. Among such sources being seriously reconsidered is geothermal energy. Because, rather tremendous water flows are associated with power production from geothermal energy there are also very significant water related problems. It is the objective of this paper to briefly review the basic concepts of geothermal energy and discuss its potential from a water management point of view.

Introduction

There are three basic types of geothermal sources. First, the rare, vapor dominated source exemplified by the Geysers, northeast of San Francisco, California, where Pacific Gas and Electric has installed numerous powerplants, the largest rated at over 100 megawatts. At the Geysers, steam is used directly as it comes from the well, superheated and with relatively small fractions of undesirable gases and corrosives. Its rarity is due to the high temperature and pressure as well as the low impurity levels at this particular site.

Second, the water dominated source is the most commonly seen in surface manifestations, though surface activity may not be representative of geothermal availability (3). The Wairakei plant in New Zealand uses a system flashing wet steam at high pressure to a lower pressure and then running the dry steam through a turbine (2). As Atmann (2)

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states, however, the chemical and thermal effluents from this plant rival those from fossil or nuclear plants. The high salinity is typical of many water dominated sources (5, 7), and accounts for the major problem of brine disposal.

Third, dry rock beds at high temperatures underground could be utilized by pumping water into the permeable rock bed at the bottom and by drawing hot liquid out at the top of the reservoir which may consist of natural or man-fractured rock beneath an impermeable rock cap. The Imperial Valley in California is estimated to have near 5 percent underlayment of hot dry rock (5) which, it is hoped, can be utilized in this way to yield 8,000,000 megawatt centuries of energy by flashing hot water.

The following table lists the existing major geothermal powerplants with their types of energy sources, as well as type of cycle.

Table 1. Existing major geothermal power developments.

Location	Type	Cycle	Capacity (MW)
1. Larderello, Italy	Dry Steam	Open System	380
2. Paratunka, USSR	Hot Water	Closed System	0.75
3. Pauzhetka, USSR	Wet Steam	Open System	5
4. The Geysers, Calif.	Dry Steam	Open System	900[a]
5. Imperial Valley, Calif.	Hot Water	Closed System	3[b]
6. Matsukawa, Japan	Dry Steam	Open System	20
7. Otako, Japan	Wet Steam	Open System	11
8. Los Alamos, New Mex.	Hot Rock	Closed System	Under development
9. Tatio Geysers, Chile	Wet Steam	Open System	Under development
10. Wairakei, New Zealand	Wet Steam	Open System	198
11. Kawerau, New Zealand	Wet Steam	Open System	10
12. Pathe, Mexico	Wet Steam	Open System	3.5
13. Mexicali, Mexico	Wet Steam	Open System	75
14. Akureyi, Iceland	Wet Steam	Open System	2.5

[a]Estimated capacity as of 1976.
[b]Estimated ultimate capacity is 20,000 to 30,000 MW.

Converting Geothermal Energy into Electricity

The cycles used in energy recovery from geothermal sources are generally of three types. The open system of Figure 1 operates by taking geothermal steam directly into the turbine as the working fluid at source temperature and pressure, exhausting it into the atmosphere after use, at atmospheric pressure. Such low cost systems are generally used only in the initial testing of a geothermal fuel or where power demands are low. With the addition of a pump and condensor the cycle of Figure 1 becomes the cycle of Figure 2 with an increase of efficiency by exhausting at a pressure maintained below atmospheric.

In the so-called binary cycle, shown in Figure 3 the energy in the hot geothermal fluid is transferred, via a heat exchanger, into another working fluid which drives the turbine. The binary cycle, generally, utilizes a fluid such as isobutane (5) which has a lower vaporization temperature than water. The lower boiling temperatures allow the utilization of energy in water not hot enough to be used efficiently by flashing. The binary cycle also has the advantage of preventing turbine corrosion by the often corrosive geothermal source water.

The three main types of cycles should not preclude the possibility of other cycles, perhaps unique to geothermal applications.

For example, the vapor pressure of a geothermal fluid could be utilized to lift the vaporized water from the warm liquid suface to a cooling shield some large distance above. As shown in Figure 4 the condensed vapor could be accumulated much like a solar still, and dropped as liquid to ground level through a hydroturbine yielding a distilled water supply and electric power. The temperature of the condensing surface could be maintained by air cooling. Such a cycle would have the advantages of eliminating many corrosion problems as well as being able to utilize relatively low temperature water.

As we examine each of these cycles from a water management point of view it becomes apparent that there are major differences in the water flows required to produce power at a given level. We have arbitrarily

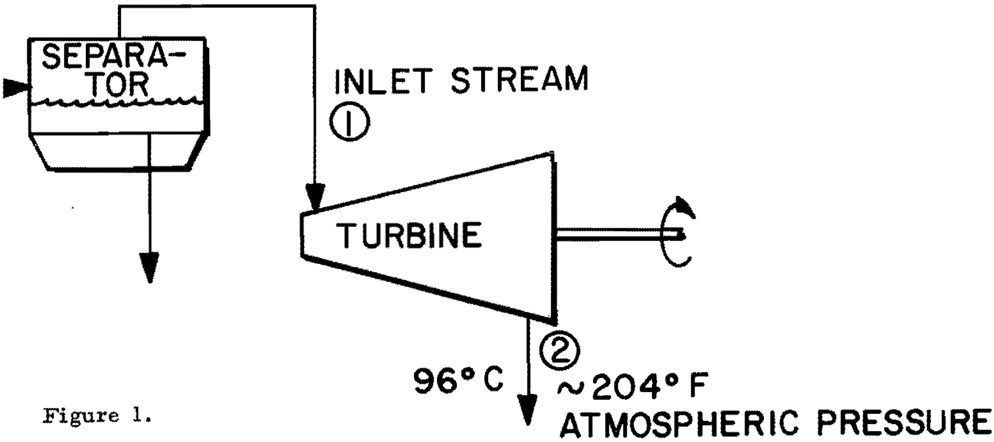


Figure 1.

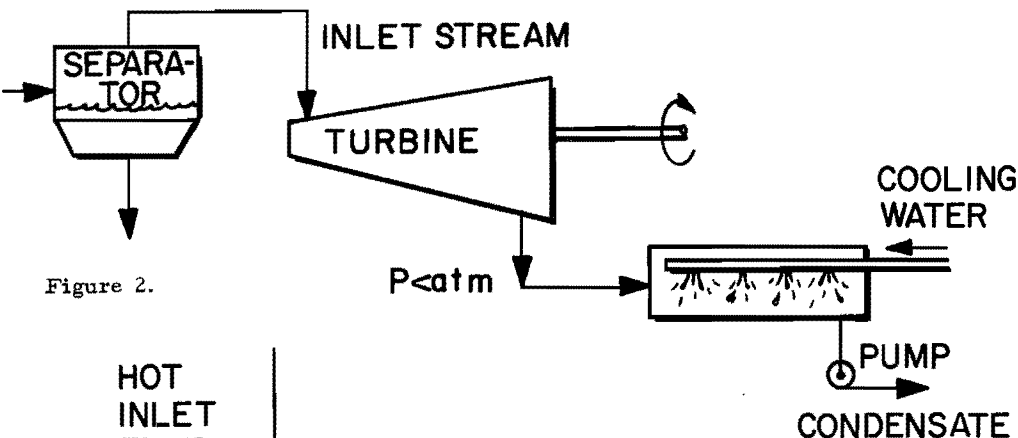


Figure 2.

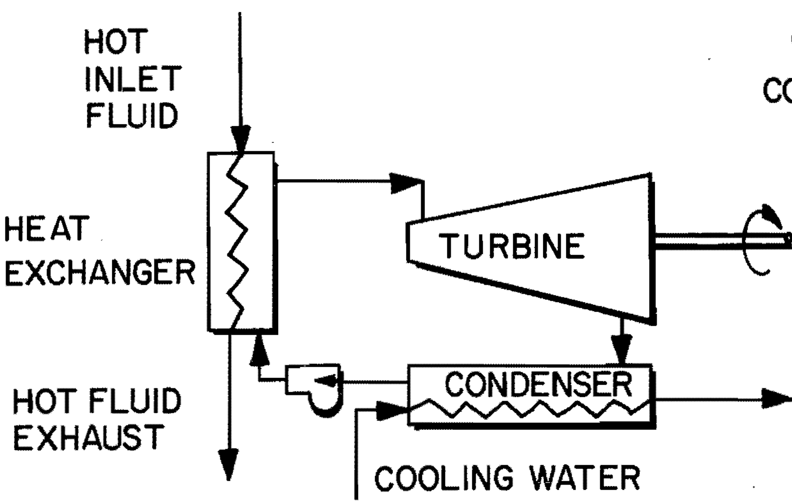


Figure 3.

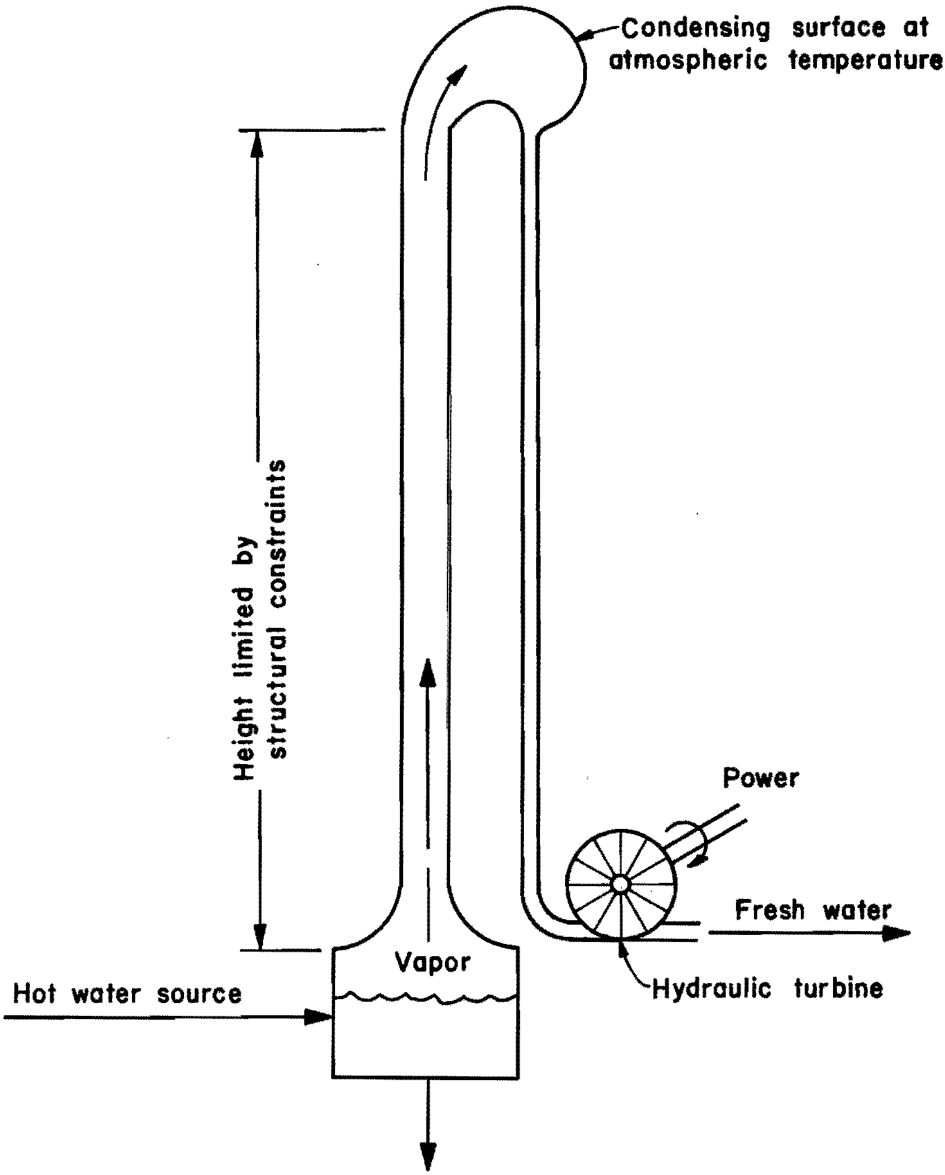


Figure 4. The geothermal hydropower tower.

selected a 10 MW plant as being representative of a typical geothermal installation. To put this number is perspective such a plant would provide the electrical power requirements for a typical community of about 90 such plants would be required to produce the power delivered by Glen Canyon Dam.

Shown in Figure 5 are estimates of the water flows associated with a typical open cycle plant which produces its own cooling water via a cooling tower. As mentioned previously such systems are used where relatively hot water is available.

Figure 6 shows approximate water flows required in a binary or closed cycle system and it may be noted that under the conditions shown the primary water flow rates are four times as great as those required in the open cycle of Figure 5.

The value of a water flow analysis becomes obvious as we examine such schemes as the hydropower tower described in Figure 4. As indicated in Figure 7 the flow rate of primary 300° F geothermal water required for a tower 500-ft high producing 10 MW of power would be on the order of 2600 CFS or more than 600 times that required for the traditional open cycle of Figure 5.

Thermal Efficiency

To put geothermal energy development in the proper perspective, a look at thermal efficiency is in order. The Carnot or ideal efficiency of a power cycle is determined by the temperatures of the heat source and heat sink utilized as shown in the following formula (Figure 8):

$$N = \frac{T_H - T_L}{T_H}$$

where N is the ideal efficiency; T_H is the absolute temperature of the heat source, in this case the geothermal water or steam and T_L is the absolute temperature of the heat sink, usually the atmosphere. Thus it is clearly evident that geothermal power plants with their relatively

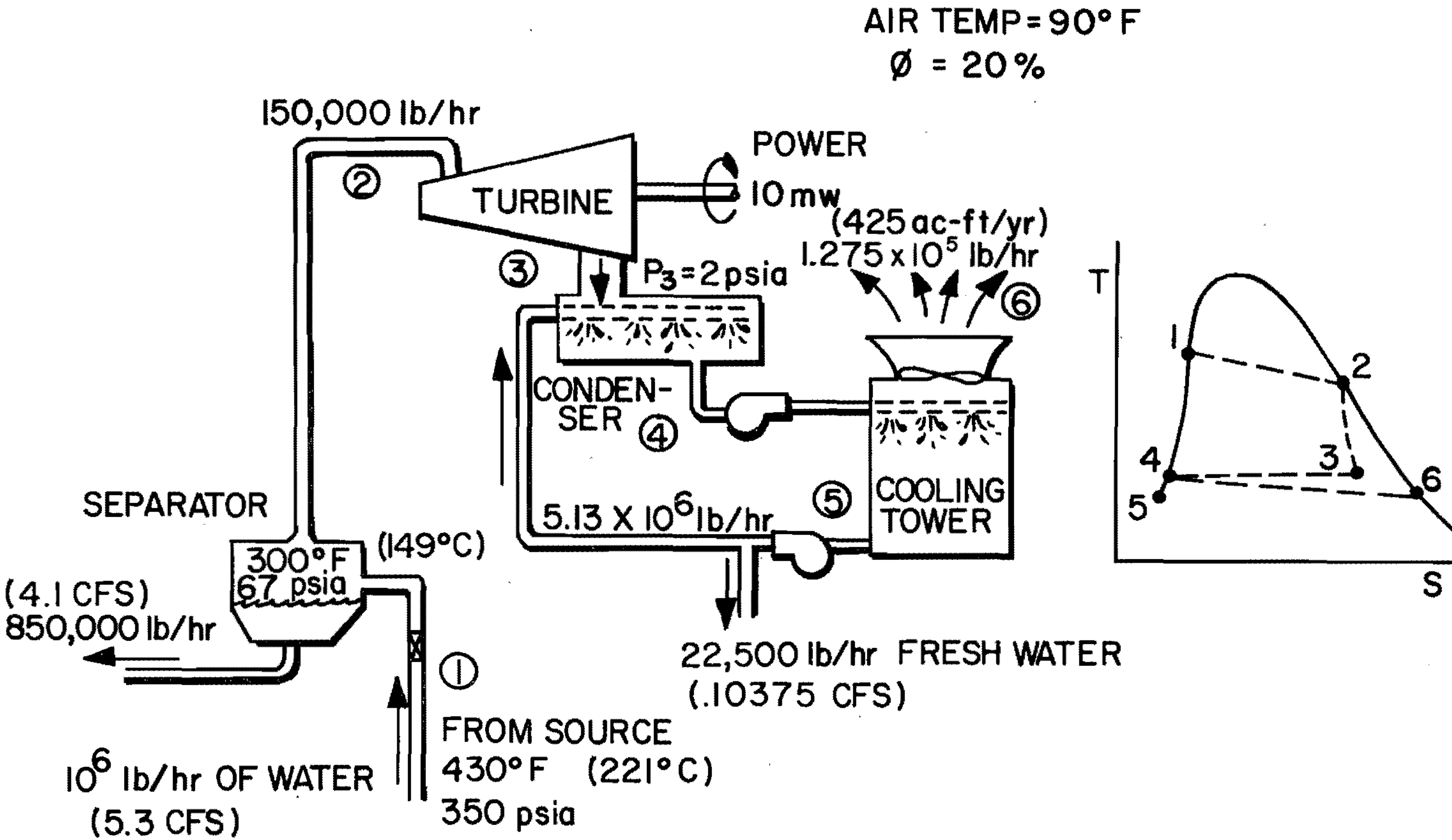
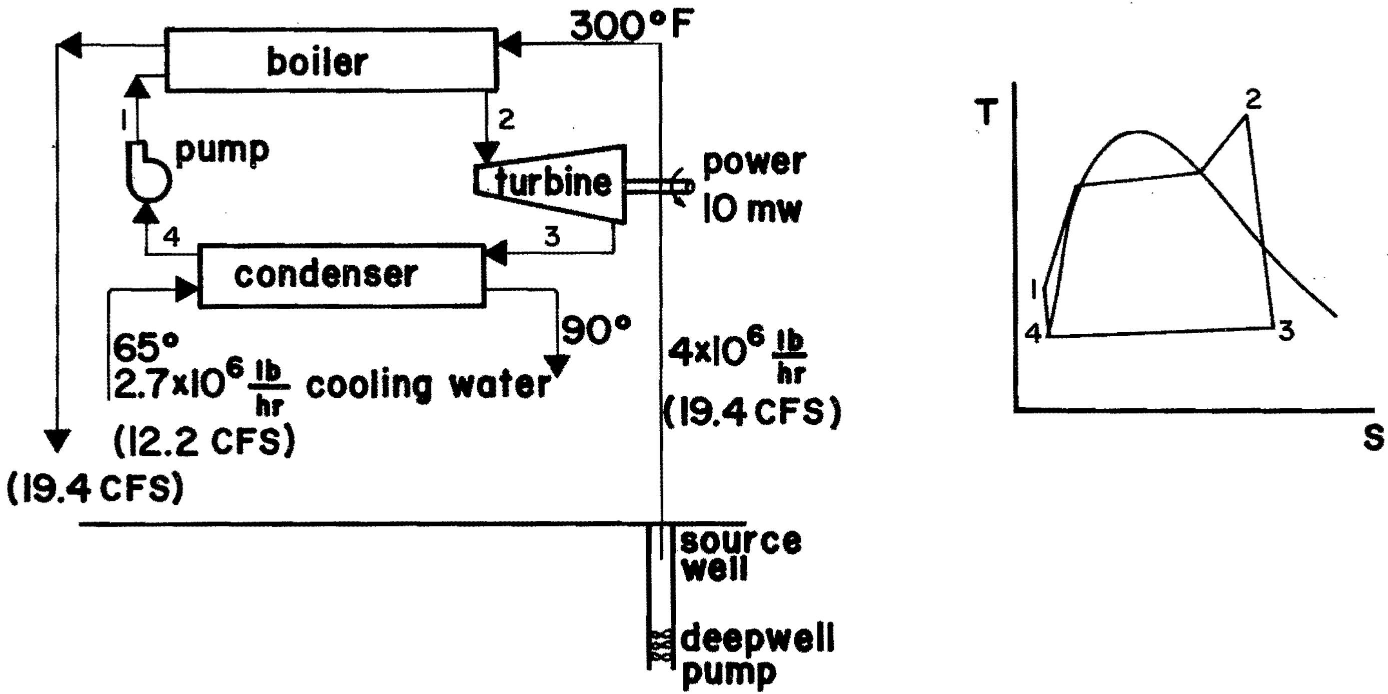

AIR TEMP = 90° F
Ø = 20%
150,000 lb/hr
②
TURBINE
POWER
10 mw
(425 ac-ft/yr)
1.275 x 10^5 lb/hr
③
P3 = 2 psia
⑥
CONDEN-
SER
④
SEPARATOR
5.13 X 10^6 lb/hr
⑤
COOLING
TOWER
300°F
67 psia
(149°C)
(4.1 CFS)
850,000 lb/hr
22,500 lb/hr FRESH WATER
(.10375 CFS)
①
FROM SOURCE
430°F (221°C)
350 psia
10^6 lb/hr OF WATER
(5.3 CFS)
T
S
1
2
3
4
5
6

Figure 5.



Closed Cycle with Isobutane as working fluid

Figure 6.

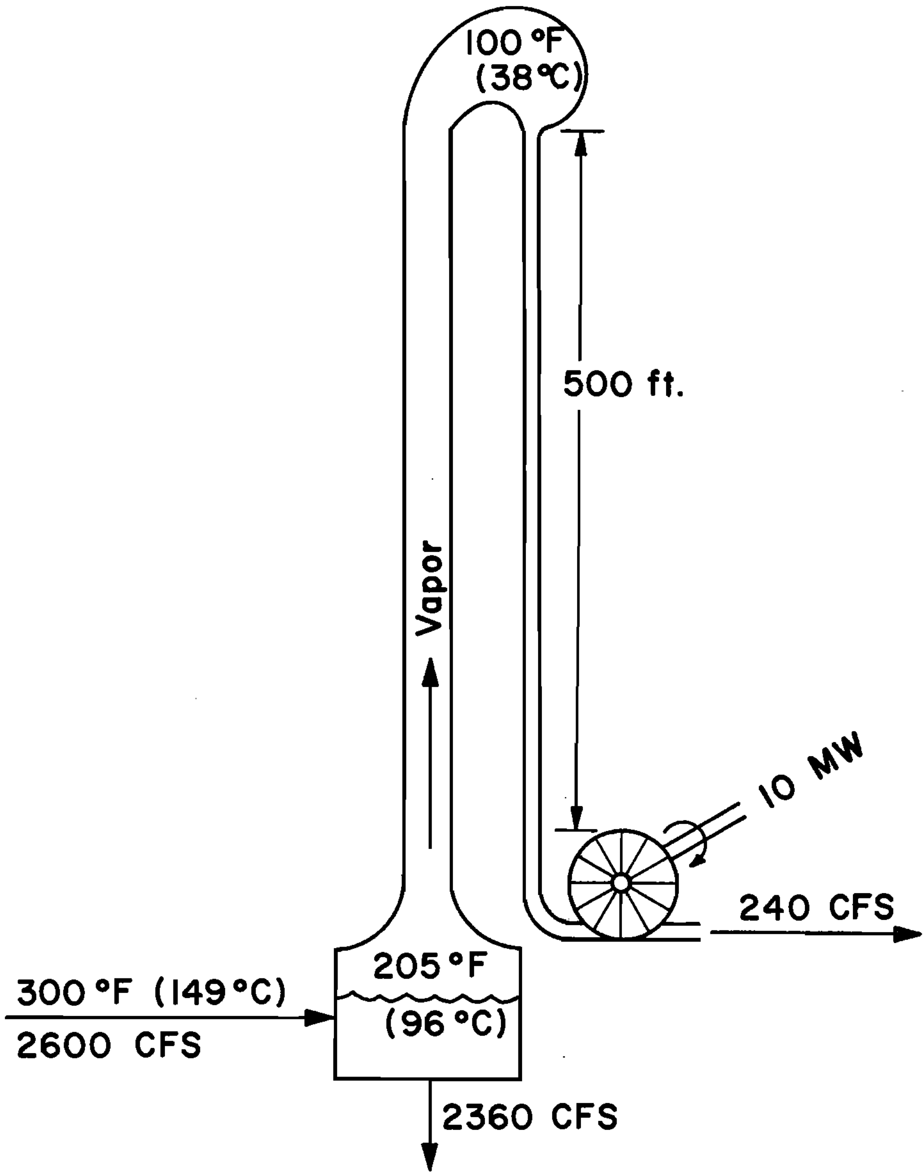


Figure 7. Water flow rates associated with geothermal hydropower tower for the conditions indicated.

Overall Thermal Efficiency

Efficiency is controlled by maximum and minimum temperatures in cycle -

$$N_{Ideal} = \frac{T_H - T_L}{T_H}$$

	Fossil Fuel Fired	Nuclear	Geothermal
Ideal	65 %	55 %	37 %
Actual	38 %	33 %	18 %
oling ater	15	22	43

Figure 8. Approximate relative efficiencies of different types of power plants.

low maximum temperatures would be expected to have relatively low thermal efficiencies. The thermal efficiency of an actual power plant is usually defined as the ratio of the energy produced to the energy that costs. In a coal fired electrical generating plant, for example, with maximum cycle temperatures of around 1000° F (538° C) about 38 percent of the heating value of the coal is converted to electrical energy.

The thermal efficiency of a geothermal power plant is a little more difficult to define because it is unclear just what is the energy that costs. Also thermal efficiency has little real value in comparing geothermal plants with fossil fuel powered plants for obvious reasons. A much better comparison is the dollar cost of KW-HRS produced.

The main point of this discussion however is that using low temperature hot water systems only a very small fraction of the total energy can be converted into electricity necessitating handling huge water flows for a reasonable power output.

Deterrents to Development

Geothermal energy is not without its problems. There are enough problems to warrant volumes of details, but Table 2 will suffice here to explain the major problems.

Probably the most important problem is that of brine disposal. Since approximately 80 percent of the volume of geothermal fluid is evaporated in cooling towers, the mineral and salt concentration in rejected water is, therefore, increased. This resulting brine must be eliminated as an environmental and health hazard since it is not suitable for agricultural or culinary use. Disposal creates its own problem with each of the main methods listed below. Desalinization would basically involve an energy consuming water distillery. Discharge to the surface water would be a dilution of the problem with significant impact considering the vast amounts of fluid required for power generation. Evaporation ponds would be much like the large flat areas that salt companies currently use to extract salt from brine in the Great Salt Lake; while

Table 2. Major problems affecting geothermal development.

1. Scarcity of information concerning the size and life expectancy of the source.

2. Lack of geophysical and geochemical instrumentation and interpretation techniques.

3. Lack of information concerning the life expectancy and well maintenance techniques.

4. Possible emissions of undesirable gases.

5. Aesthetic problems associated with well drilling and testing and with plant development.

6. Environmental problems associated with vapor emissions from the cooling towers (steam plumes).

7. Disposal of liquid wastes.

8. Well drilling technology consistent with the unique characteristics of geothermal development.

9. Mufflers for noise abatement may not be sufficiently effective.

10. Land subsidence in the vicinity of the well.

11. Waste heat discharged into the environment.

12. Legal and institutional problems.

13. Economics of geothermal compared with other sources of energy.

14. Corrosion and abrasion on mechanical equipment.

15. Hot water pump technology.

16. Possible increase in earthquake hazard produced by both withdrawal and reinjection of hot water.

17. Geothermal power generating installations need to be located at geothermal sites which might be at considerable distances from load centers, with a resulting loss of energy through the transmission process.

export would mean piping, most probably, to carry the fluid to a more convenient depository. Reinjection is the method used at the Geysers, California and has worked well so far with a pump at a not excessively distant well to put the brine back into that well where it will theoretically join with the geothermal field water and be possibly recycled. The advantages and disadvantages are listed rather concisely in Table 3 . Time and space do not permit elaboration.

Alternate Uses

Because only a small fraction of the energy in a hot water geothermal resource can be converted into electricity, one looks to alternative uses of geothermal energy. Many energy dependent processes do not require the high temperatures required for efficient power production. As with 200 residential and commercial establishments in Boise and over 400 in Klamath Falls, Oregon, (3) space heating and water heating could use even sub-boiling temperature water; the same energy source could run heat pumps to air condition in the warmer months. Greenhouse temperature maintenance for large scale intensive farming, a deterrent at present due to high energy costs, could be achieved readily, as is done in Lakeview, Oregon, with many of the relatively low temperature geothermal sources (3).

Food processors using typical maximum temperatures of 240° F to 270°F are showing an interest in using geothermal energy which is unsuited to efficient power production (1, 4, 9, 11).

Natural gas heat to keep beef feedlots warm and dry is considered by one operator to be a good investment (6) but geothermal energy could be an alternative on a much larger scale.

Methane production from animal wastes or vegetation requires warm temperatures for fermentation processes (8) which temperatures could be easily obtained from most known geothermal sources.

Mineral recovery, agriculture, water desalinization all have similar applications to utilize the geothermal energy. (See Table 4 .)

Table 3. Alternate methods of brine disposal.

Technique	Advantages	Disadvantages
Reinjection	• reduces the likelihood of land subsidence • regenerates the water source • reduces pollution hazards to surface and ground-water supplies	• salt precipitation resulting from lowered brine temperature might tend to reduce the priority of the reservoir material • pollution hazards to groundwater aquifers overlying the thermal reservoir • capital and operating and maintenance costs associated with the re-injection well
Evaporation Fonds (complete containment)	• reduces pollution hazard to surface and ground-water supplies • recovery of minerals having economic value	• requires large land areas • may require lining to prevent seepage to groundwater • aesthetics • ground fog
Discharge to Surface Water	• low cost of disposal	• salinity pollution • thermal pollution
Export	• eliminates local problem • water may be used as a vehicle for solids (such as coal)	• high cost of transport • tranfers the problem to another area
Desalinate	• use power to desalinate brine • supplemental fresh water supply • recovery of minerals having economic value	• lower volume more concentrated brine • cost of power used for desalination

Table 4. Potential uses of geothermal resources for other than power production.

Heating homes and commercial establishments
Air conditioning
Aquaculture
Greenhouse heating and cooling
Food processing plants
Livestock production units
Methane production units
Desalination to obtain fresh water
Mineral recovery

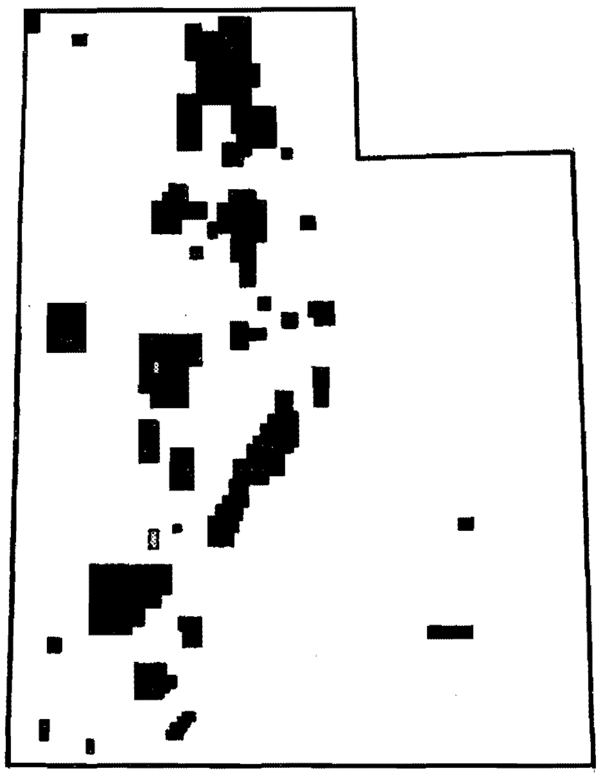
Utah's Sources

As attention is turned now to the geothermal resources in the Utah area, three prime considerations emerge from the previous discussion: 1) High temperature and pressure, or in other words, thermodynamic availability of energy in the source; 2) cold water source for cooling towers; and 3) low mineral and gas content, though this can be waived to some extent with the binary cycle mentioned.

The second and third considerations seem at first to make geothermal energy a competitor for other fresh-water users, notably agriculture. However, if the geothermal source is free enough from impurities, then the 20 percent, approximately, of the geothermal water not evaporated in towers (5) can be added to the cooling water released, to increase the total supply of water. If there is an undesirable brine content, then the evaporation increases this concentration making the problem more severe, and, thus, favoring reinjection, results in a water loss.

Figure 9 indicates the areas of Utah considered to be potential geothermal resource areas. The darker areas are known geothermal resource areas. Present surface manifestations have a maximum temperature at Roosevelt 192°F (89° C) with others in the state at 175° F (79° C), 156° F (69° C), 146° F (63° C), and 132° F (56° C) being the only springs over 97° F (36° C). The water in all these springs is currently used for culinary and irrigation purposes though stray H_2S and mineral deposits at Roosevelt and mineral deposits at Thermo, the 175° F (79° C) spring, have been noted (12).

The map of Figure 10 superimposes fault zones on a map of the major thermal springs in Utah. This map was constructed as part of this study by surveying the bottom hole temperatures of many wells around the state in an effort to assess the dual capabilities of current water sources as well as to locate potential geothermal areas. It is realized that these wells were drilled for water, not energy and a superficial examination such as this would be only indicative of the necessity of an in-depth study of the geothermal sources.



Legend

Known geothermal resource areas

Potential geothermal resource areas

Figure 9. Geothermal resource areas in Utah.

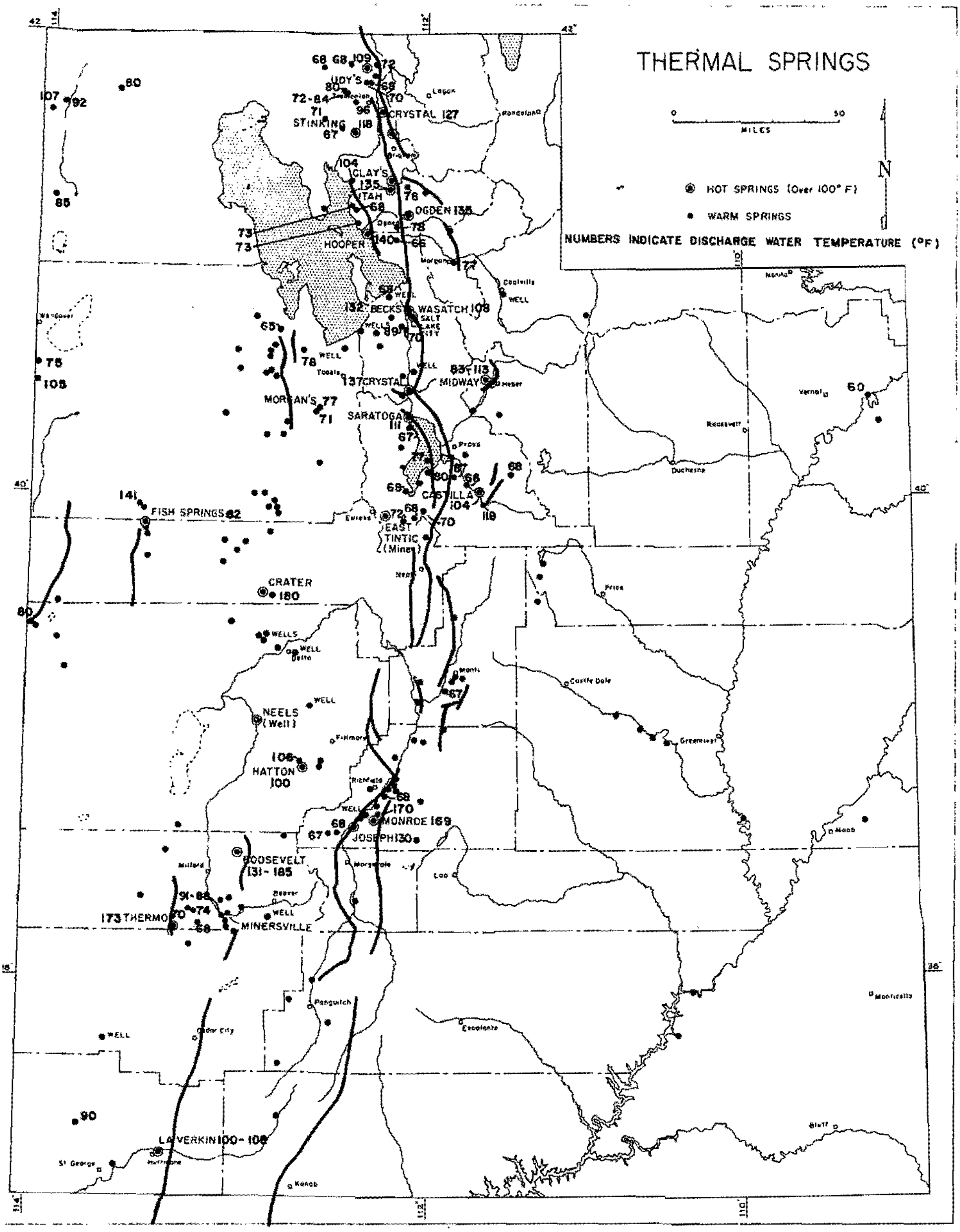


Figure 10. Locations of major thermal springs and fault zones in Utah.

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GROUNDWATER QUALITY ASPECTS OF UTAH'S EXPANDING COMMUNITIES

by

Bruce N. Kaliser*

With population influxes brought about as the result of energy and mineral resource related developments in Utah, there is a rapidly increasing requirement for additional municipal services. More or less instantaneous burdens have already been placed upon existing water and sewage facilities. Officials at all levels of government are desperately trying to cope with the situation.

To illustrate this population growth for two portions of the State some figures are provided. The Uinta Multicounty Planning District, consisting of Uinta, Duchesne and Daggett Counties, had a 1970 population of 20,648. Conservatively this is judged to go to 35,434 by the end of 1975 and 37,133 by 1980. Less conservatively, the 1975 figure may be 37,258 and the 1980, 53,440. The former population projection represents increases of 72 percent and 80 percent, and the latter 80 percent and 159 percent, respectively. The Five County Planning District, consisting of Beaver, Iron, Garfield, Kane and Washington Counties, is anticipated conservatively to go from 35,224 people in 1970 to 44,802 in 1975 and 67,235 in 1980, increases of 27 percent and 91 percent respectively. Alternatively, less conservative projections indicate populations of 50,024 in 1975 and 91,884 in 1980, representing percentage increases of 42 percent and 161 percent.

There is normally a considerable time lag between the time at which demands are first felt and financing is made available for public utilities, let alone installation of the utilities. With regard to water this frequently means the necessity for families or subdivisions to dig water wells. Since the requirements are principally for domestic water, individuals desire to utilize shallow groundwater whenever

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possible. Each residence is likely to install an individual sewage system; probably, in Utah, a septic tank with drainage field.

Many geologic environments are being encroached upon for the first time. The hydrogeologic regime in many of these areas, though in semiarid to arid climatic zones, is sensitive as far as water quality is concerned. Groundwater in bedrock may be of lower quality than groundwater in overlying soil materials, depending upon the bedrock lithologies and distances of migration for the enclosed groundwater. Exploration for suitable aquifers in bedrock and sophisticated procedures of pump testing of individual water zones and well construction are more than likely to be out of the picture for a single residence's domestic requirements. Wherever possible there will be emphasis upon the shallow unconfined water table in soil materials, a situtation which is more prevalent than many people believe to be true in Utah.

Protection of the quality of this vital shallow water resource is therefore vital. Because of its widespread occurrence just below the surface, just out of sight, the ease with which it may be effected is not readily appreciated. In any areas where developments are foreseen, exploration of the hydrogeologic regime should precede urban or other encroachment. Recommendation may thereby be made for adequate disposal of all waste. Mobile home communities are no less faced with requirements for water and waste disposal and now-a-days these are not the ephemeral establishments that they were once thought to be. With their creation just outside city limits, the occupants may bring animals along with them. The relatively small yards concentrate the animal wastes as well as other possible wastes on the surface. The hydrogeologic regime may be such so that precipitation or irrigation waters may have direct access to the water table close to the ground surface. The soil materials may be clean, coarse grained sand or gravel and therefore offer no potential for filtration of the downward migrating polluted water. From these same shallow aquifers comes the culinary water tapped by wells. The hazard becomes obvious. But the hazard can be assessed and necessary protective measures taken prior to any development.

In the event that the shallow groundwater is already unsatisfactory in quality for domestic culinary use, baseline studies should still be conducted prior to developments. Perhaps the quality can be enhanced in the future. A change of irrigation or grazing practices in the recharge area may occur. Water of subculinary quality is still a resource and perhaps a no less valuable resource at that. There must come a time in Utah and throughout the West, if indeed not throughout the country, when all waters will see maximal utilization. Shallow groundwater is a resource available at minimal cost of exploitation and stored at no cost to man, either for construction or maintenance. Even the aesthetic considerations are nil. But man has yet to learn to appreciate these facts and where necessary draw differing quality waters from different subsurface reservoirs to accommodate distinct needs.

There is much to be gained by a more satisfactory approach to the utilization of shallow groundwater. Intentional lowering of the shallow water may even save a number of communities in Utah from bankruptcy. Very many of Utah's cities and towns are faced with the severe problem of infiltration of groundwater into the sewage collection system. Significant percentages of the wastewater treated are totally needless quantities because of this factor. Municipal wastewater treatment plants are overextended for this reason along in many cases.

A means of wastewater treatment in Utah that is growing in popularity is the sewage lagoon. It too, however, requires proper siting with respect to hydrogeologic regimes. One must consider that under static conditions the lagoon cells may eventually leak effluent. Under dynamic loading, such as an earthquake, there may be failure of the substratum or the earth embankments comprising the lagoon.

Generation of greater quantities of solid waste leads to the need to locate additional sites for sanitary landfills. It is no less important that they, too, be properly sited. All manner of deleterious substances normally end up in a solid waste operation. Some items may contain concentrations of trace elements, which, should they reach the groundwater regime, might disperse to contaminate a significant subsurface reservoir of otherwise exceptional quality water.

Recognizing that there are other factors to consider than the hydrogeological, it is nevertheless important that this factor not go ignored. Officials in Utah's cities and towns are becoming more alert to the situation with which they may be faced if they're not already. They and their engineers are involved in preparing population estimates, acquiring necessary land and easements, submitting applications for financial assistance, gaining approvals from regulatory agencies and designing facilities to accommodate the population growth. Let's not forget that the terrain evaluation, however, should come early enough in the procedure so that the conclusions prove not to be a hindrance but rather a great help in identifying and overcoming any potential groundwater pollution problems.