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by

John E. Keith and Rangesan Narayanan

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WATER USE TRADEOFFS BETWEEN ENERGY AND AGRICULTURE

John E. Keith and Rangesan Narayanan*

Introduction

Water availability and use has a history of conflict in the arid West, and the large-scale development of the energy resources in the Upper Colorado River Basin and the Great Basin can be expected to add to the competition for water. In addition, air and water quality have also become major parameters in the allocation decisions. It is not clear whether energy development will have a detrimental or beneficial effect on water quality in the region, at least with respect to salinity which is the currently acknowledged major quality problem in the Colorado River System. The institutions and circumstances under which energy development takes place are critical with respect to water quality. Several recent research projects at Utah State University have been focused on both the quantity and quality constraints on water use in Utah. The results are the bases for this paper.

The Setting

Utah falls into two separate major drainage basins: The Upper Colorado River Basin and the Great Basin. The former basin is a part of the Colorado River System, which provides water to seven states and Mexico. The latter is contained inland. The Utah portion empties into the Great Salt Lake or Sevier Lake. In addition, each of these basins can be separated into hydrologically distinct subbasins as shown in Figure 1. Utah's share of the Colorado River water has been adjudicated

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LEGEND

- POWER PLANT
- COAL
- △ TAR SANDS
- OIL
- ◇ GAS
- OIL SHALE
- CONVERSION PROCESSES
 - CS • COAL SLURRY
 - L • LIQUEFACTION
 - G • GASIFICATION
 - R • REFINERY

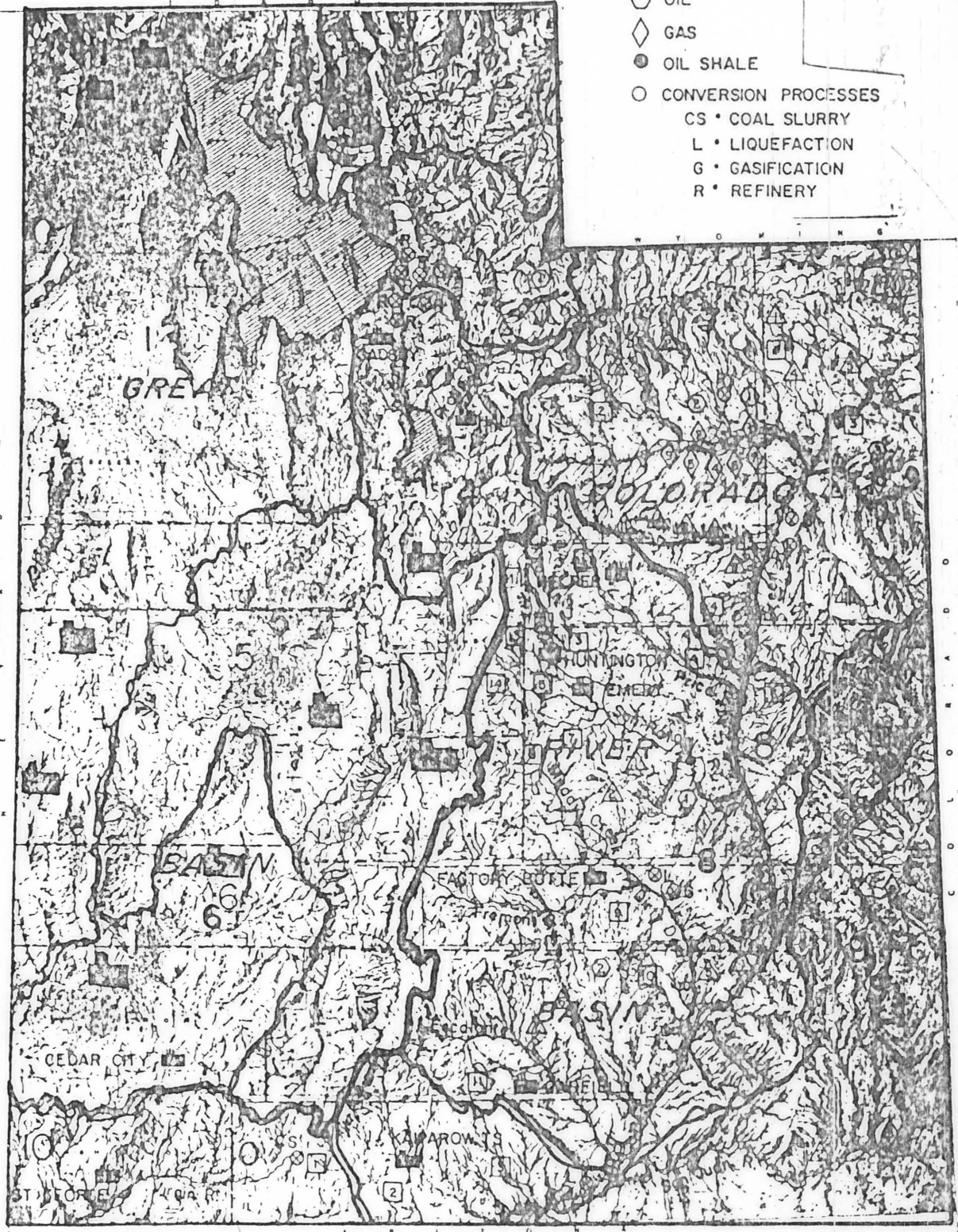


Figure 1. Map of hydrologic study units of Utah.

by both the division between Upper and Lower Colorado Basins and by compact among the Upper Basin States. Other agreements have been made for the allocation in the Bear River sub-basin. In general, Utah and most other western states have promulgated the idea that available water is critically scarce, and must be husbanded to provide for economic development. Heavy snowmelt runoffs in the spring must be captured to increase summer water supplies.

The primary energy deposits in Utah are found in the Colorado River Basin, although some of the processing and use of those resources are planned for the Great Basin drainage. Also, evident are relatively large amount of various kinds of energy resources, including coal, oil shale, tar sands, and uranium, and the variety of potential developments, including synfuels, electricity, and direct export. The development of alternatives to imported oil, coupled with the notion of water scarcity, has prompted many observers to suggest that energy development in Utah will take place only by reduction of water use in other sectors.

Finally, the application of air and water quality constraints have added complexity to the water allocation problem. Public Laws 92-500 and 93-320 impose three distinct types of restrictions on water use: 1) Maintenance of current stream quality (non-degradation), 2) Temporally increasing strigency of end-of-pipe levels of treatment and discharge, culminating in zero discharge, for point sources, and 3) an as-yet-to-be-determined policy toward non-point sources, which could vary from an in-stream standard to imposed treatment practices for both end-of-pipe emissions (e.g. canals) and water application procedures (e.g. trickle irrigation). Air pollution, including particulates, and sulfur and

nitrogen oxides, also may play an important role in the location of energy development so that the water allocation problem is compounded. The designation of extremely limiting air quality standards for National Parks, Forests, and Recreation Areas may have crucial bearing on whether, where, and how energy resources may be used.

For many years, the environmental and other spillover effects were ignored by developers. Recently, environmental quality considerations have severely restricted the development activity. Given the impending creation of the Energy Mobilization Board, with its powers to override environmental constraints, and the urgency evidenced toward energy development. It is now incumbent on administrators to systematically and carefully weigh the benefits and costs of projects. Adequate information about these costs and benefits must be forthcoming from researchers. The "interconnectedness" of the problems, costs and benefits suggests general-equilibrium systems-oriented approaches to research and information generation, rather than piecemeal, project-by-project studies. Research at Utah State University has employed systems analysis to generate information about optimal energy developments and their locations, the associated changes in competing uses, such as agriculture, and the resulting environmental consequences.

The Models

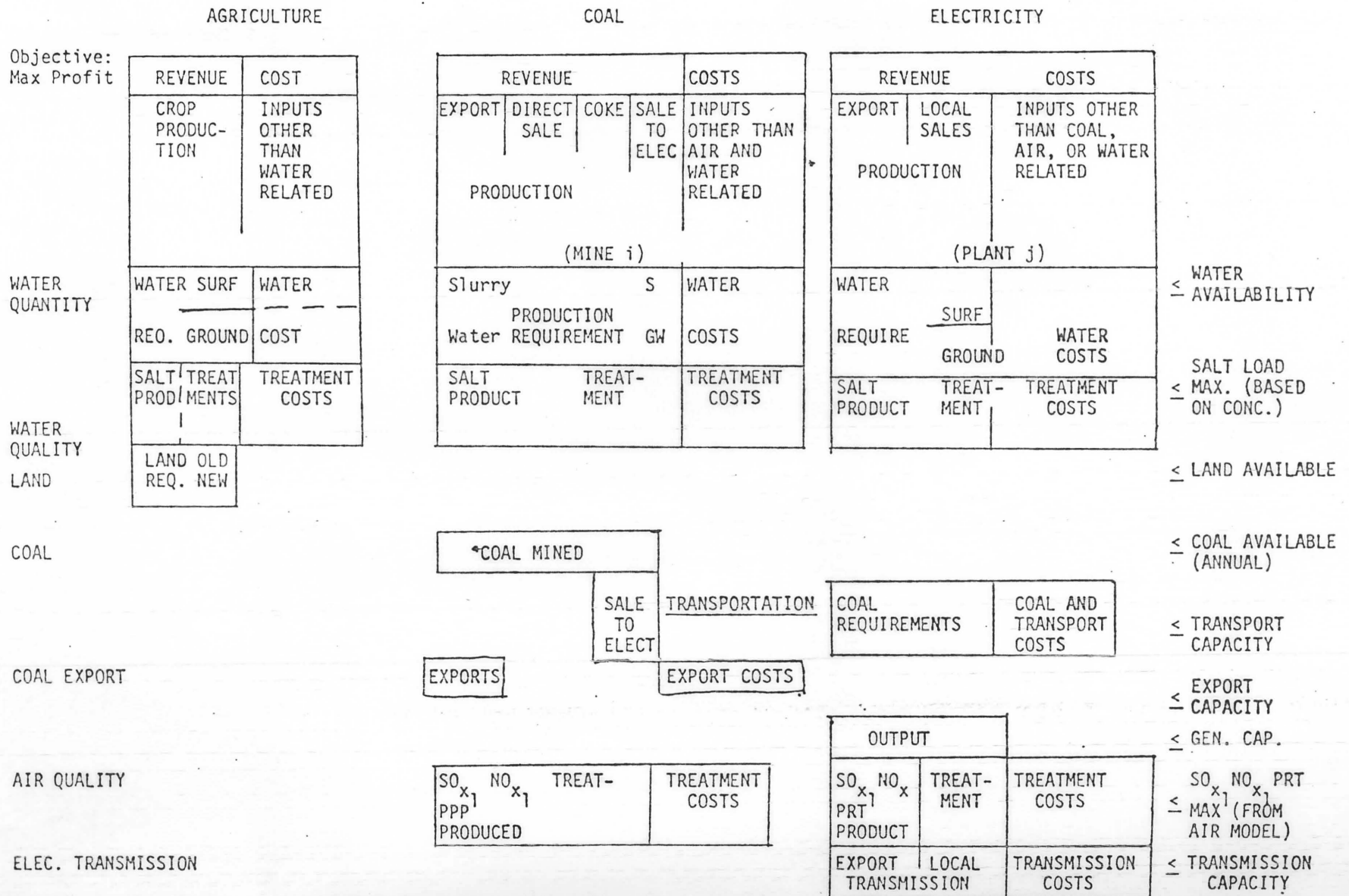
These systems approaches utilized in the various research projects were linear-programming models, which maximized profits to the agricultural and energy sectors of the economy subject to water and resource availabilities, and environmental constraints. Detailed descriptions of these models are available in several publications (Glover, et. al, 1979; Keith, et. al, 1978; Narayanan, et. al, forthcoming). Basically, the models included net profit

objective functions, various production activities, and resource and environmental constraints. Figure 2 illustrates the general structure of the models. The objective functions included returns to product sales for each sector, or activity, net of all costs but water, land, energy resource input, transportation, and environmental control costs and the costs associated with various levels of each of those activities. Activities included various crops and intermediate and final energy outputs. Water, land and energy resource input requirements for each production activity, and environmental effluents produced by each activity were specified. Effluent treatment activities were also available to each sector, based on current treatment technology. Constraints included water availability, net of existing municipal and industrial uses and a wetland requirement, land availability, classes as irrigated or potentially irrigable, annual energy resource availability based on specified time horizons for exhaustion by type of resource, processing and inter-regional transportation capacities, and environmental pollution restrictions.

These models were used to generate either the demand curves for inputs, using the shadow prices derived through parameterizations of resource availability, or the supply curves of inputs, using the dual value of parameterized requirements for the resources by each activity. Any solution generated was economically efficient, given the specified constraint system, so that the effects of alternative institutional and other limits on an otherwise competitive market were examined.

The data collection for the models was extensive, and sources may be found in the respective publications, including farm budgets from annual Agricultural Statistics publications (Utah State Department of Agriculture), bulletins from the Bureau of Mines, Department of Energy, Electric Power Research Institute, and others. Some specific areas may be of special

FIG. 2. GENERAL MODEL FOR EACH STUDY UNIT (GEOGRAPHICAL - HYDROLOGICAL)



interest. Electric power plant site areas were identified using an air quality modeling procedure, which generated isoplaths of maximum power generation, based on 3-hour source-to-obstruction limits. These isoplaths were generated for each coal source from emission rate calculations for each plant and coal combination. Transportation to the site areas from the coal sources was also modeled, based on cost and construction data from railroads, trucking firms, and slurry developers.

Salinity concentrations were also converted to loading, or emission levels. When reductions in loading from agriculture occurred, the allowable salt loading was increased, in order that current concentrations could be maintained. All costs and price data were on a 1976 base; either as obtained from original sources or updated by appropriate indices. Water development costs, for example, were updated using the 1976 construction costs indices. While such a brief description of the models used is inadequate for complete knowledge, time and space constrain further descriptions. Additional modeling details are available on request.

Model Results

Model results were obtained for a broad range of resource and institutional constraints. Both water quantity and quality aspects were examined.

Water Quantity

First, various levels of energy development were allowed, subject only to water and other resource availability. Implicit was the assumption that water rights were fully transferable among users. Results for these solutions indicated that water availability is not a significant limiting factor for probable energy development within the Colorado River Basin in Utah in the near future. Using either the projections for the year 2000

from the U.S. Department of Energy (originally Energy Resource and Development Administration), which included 6000 MGW electricity, 450,000 barrels of syncrude per day from oil shale and 100,000 barrels per day from coal liquifaction, or an alternative which excluded synfuels but included 12,000 megawatts of coal-fired electrical generation plants (double the ERDA projection) no appreciable change occurred in current irrigated agriculture in the Colorado Basin. Only when oil shale was expanded to an excess of 5 million barrels per day, tar sands were included at 2 million barrels per day, and full electrical capacity of 12,000 megawatts was allowed, was current irrigated agriculture essentially eliminated. In general, the oil shale and tar sands developments were projected to be by far the largest consumers of water. Additional solutions were generated for 12,000 MW of electrical generation, oil shale production of 250,000 barrels per day, tar sands of 130,000 barrels per day, coal gasification of 250 million cubic feet per day, and coal liquifaction of 100,000 barrels per day. In this case, no change in present irrigated agriculture was indicated (Keith, et al, 1978). The addition of a 12,000 MW nuclear plant, however, reduced irrigated acreage, primarily irrigated pasture, by approximately 60,000 acres. (Keith and Turna, 1978) In the Great Basin particularly the Sevier River sub-basin, water availability is a limiting resource. Development of electrical generation capacity is accompanied by reducing irrigated acreage. For the 3,000 MW plant reductions of 1 to 11 percent in existing irrigated land could be expected depending on alternate cooling water use technology (Narayanan, 1978). In no case, however, were additional large-scale storage facilities developed. The marginal value of water in energy was relatively large compared to agriculture, so that water transfers between the two sectors were indicated, but the marginal value of water in agriculture

was insufficient to support storage projects. A two-season model was developed (Snyder, forthcoming) because the runoff in the Western U.S. typically follows a pattern of large springs and small summer water availabilities. The two season model would generate a better analysis of water value. However, results still indicated transfers of water from marginal agriculture to energy for large-scale energy development, but no increase in storage capacity.

An examination of the effect of institutionally constrained water rights transfers was undertaken (Turna, 1979). The effects of limited water right transfers and transfers of diversion water rights were studied. For the limited transfers, it was assumed that water rights could be purchased only from users in a specific drainage, or sub-basin. Thus, within an upstream basin, water would be allocated efficiently but the value of water to downstream users would not be considered. Thus, potential gains in regional profits might be eliminated. Most transfers in Utah do take place within specific hydrologic regions. Results indicated that little loss occurred, as long as energy development remained moderate, simply because additional water rights are available in most sub-basins. With large-scale development of energy resources, however, significant losses were generated (10 percent of total profits), since lower marginal valued energy production would take place upstream at the expense of higher marginal valued production downstream.

Allowing transfers of diversion rights from agriculture to energy, rather than consumptive use rights, causes externalities to downstream users, since energy processing is expected to use a higher percentage of diversions. In fact, most energy developments will institute total containment of waste water to avoid effluent problems. Thus, current

irrigation return flows would not be available to downstream users. Actual Utah law and practice are not clear in this respect. Several court decisions suggest downstream flows must be maintained (consumptive use right only), yet these rights have not necessarily been protected in allocative decisions by the State, nor are all court decisions consistent. Some externalities existed for moderate levels of energy development, due mainly to the restricted water availability in one upper reach of the Colorado River Basin. With large-scale development, however, the externality problem assumed significant magnitudes (10 percent of total profits).

Several basic conclusions were derived from the studies related to water quantity:

1. Water availability is not a constraint on the development of the moderate levels of energy resources are most probable in the foreseeable future, except in the Sevier River Sub-basin.

2. Water quantity will be constraining on irrigated agriculture if large-scale energy developments occur, in that the water will be transferred to high value energy uses from lower valued agricultural activities.

3. The kind of institutional constraints on the market for water rights, may have a significant impact on total profits generated in the event of large-scale development; and

4. No further development of large-scale storage facilities appear to be warranted by either energy or agriculture, at least for the near future.

Air and Water Quality

The introduction of air and water quality constraints had significant impacts upon the model solutions. First, the air quality constraints

reduced the maximum electrical generation and other energy resource processing capacity rather substantially for several of the subregions in both the Colorado River and Great Basins, (Glover, 1979 and Snyder, forthcoming). Thus, the air quality limits to production, as established by the U.S. Environmental Protection Agency, appear to be sufficiently constraining so that little or no tradeoff was generated between agriculture and energy development in the Great Basin (except in the Sevier River Sub-basin.) The air quality modeling has not as yet been completed for the Colorado River Basin. Preliminary results indicate, however, that there exist several sites capable of supporting energy production while meeting EPA standards. It is doubtful that the maximum allowable capacity given current air standards would result in reductions of current irrigated acreage in the Colorado Basin, either. Water quality, however, does impose some restrictions.

The Department of Energy projection of probable energy production levels for the year 2000 in the Colorado Basin in Utah would result in an increase of about 25,000 acre feet of consumptive use, which is less than a 1 percent decrease in water flow. Narayanan et.al. (forthcoming) report that the development of the projected level of energy production in all the Upper Basin states, coupled with an additional 230,000 irrigated acres, would result in less than a 10 percent increase in salinity concentration at Imperial Dam. Full scale energy development in Utah alone would reduce outflows and increase salinity by about 3 to 5 percent. The imposition of non-degradation standards have significant allocational effects in the Upper Colorado Basin, according to the model results. A strict nondegradation standard would prevent further development of the 300,000 to 600,000 acre feet of Utah's unutilized portion of the Upper Basin share of water which currently provides dilution

of natural and agriculturally-related salt loading.¹

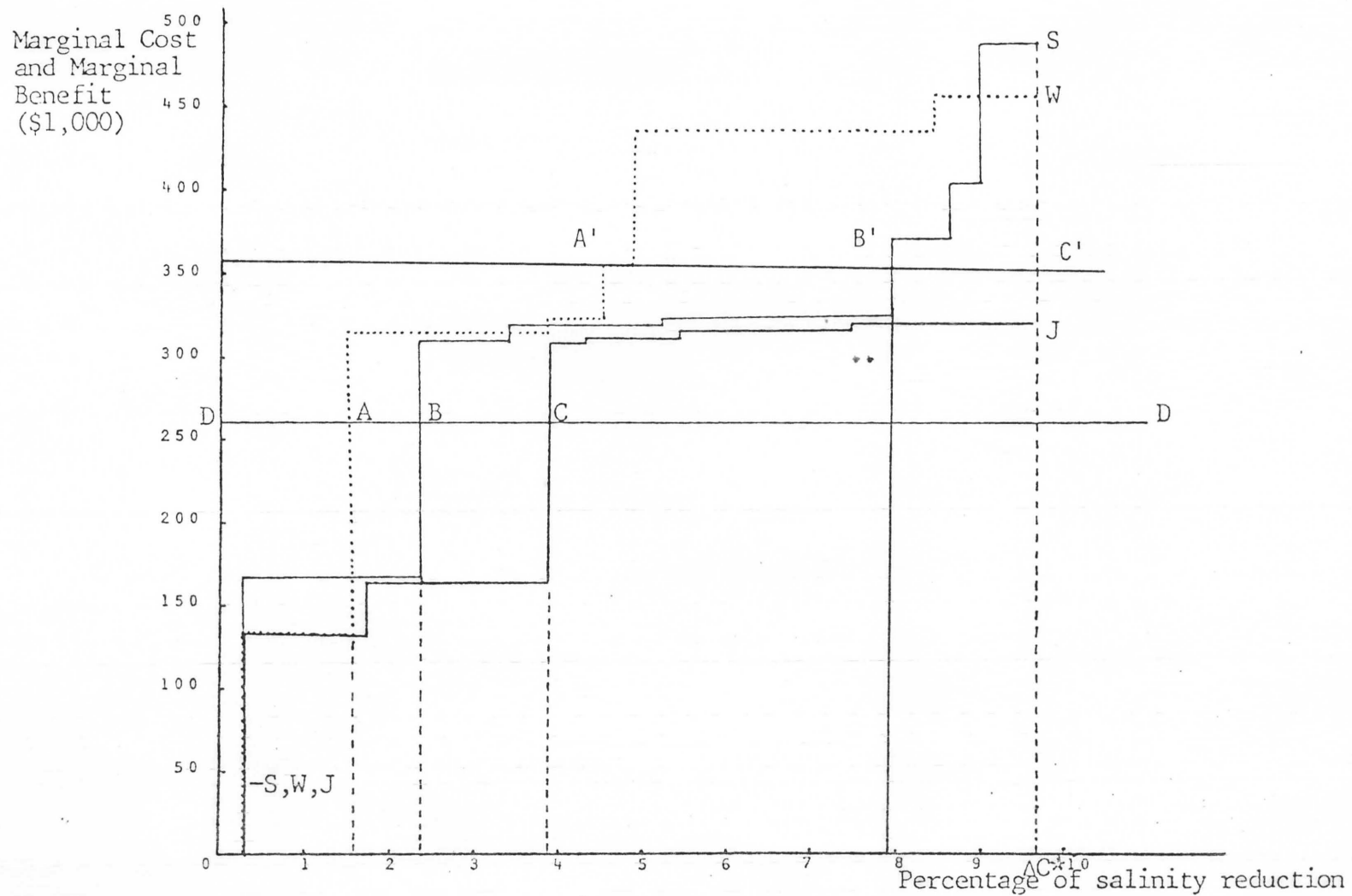
If water quality does in fact limit consumptive use to present levels, there may be an increase in water quality as energy resources are developed ceteris paribus. Water use will not increase (assuming water rights downstream are protected), but salt loading from existing agriculture will be reduced. Depending upon the area in which irrigated agriculture is retired, loading may be reduced very substantially. Selective retirement through state approval of water right transfers may be a significant tool by which stream standards are met, energy developed, and impact on irrigated agricultural in the Colorado Basin mitigated. For example, Grand Valley irrigators contribute a substantial amount of salt loading relative to Green River irrigators. Retirement of Grand Valley irrigation, by transfers of water rights within that area to energy development, may allow both energy development and some increase in irrigated acreage in the Green River drainage. Model results indicate this procedure to be optimal, since irrigated crops are similar throughout the Upper Colorado River Basin.

Several studies have examined possible irrigation practices which would reduce salt loading from return flows and thereby allow the use of at least a portion of currently unallocated water. The primary treatment practices currently under consideration are 1) conversion of some traditional irrigation systems to sprinkling, 2) canal lining, and 3) construction of evaporation ponds and desalting plants. Results from the

1. The rather large variance in unutilized water is the result of the definition of allocated water rights. Currently 600,000 acre feet have not been patented, but approximately 400,000 of those acre feet have been conditionally allocated to various users.

models indicate that each of these practices will be undertaken to some degree while maintaining a positive, but reduced, profit in agriculture. In several cases there is obvious need for a subsidy, if maintenance of irrigated acreage is a policy objective, since long term profitability is very low relative to the costs of borrowing and the opportunity costs for alternative investment.

Narayanan, et al. (forthcoming) examined the economics of three alternative practices for the Upper Colorado River Basin--increased agricultural efficiency through sprinkling and canal lining, treatment of salt discharges, and a combination of those practices--assuming the Department of Energy projections and new irrigation were in place. Figure 3 indicates the results from the study. The marginal cost of reduction of salinity which is produced by energy and agricultural development is indicated in the figure, and includes the annualized investment, operation and maintenance, and foregone income (where appropriate) costs for each alternative treatment. By comparing these costs with downstream benefits, some measure of economic efficiency with respect to salinity control can be estimated. Benefits to reduced salinity in the Lower Colorado Basin in the form of reduced damages to agricultural production and municipal and industrial users have been estimated by several researchers (Skogerboe and Walker, 1972; U.S. Department of Interior Environmental Protection Agency, 1971; Kleinman, et al., 1974; Valentine, 1974; Andersen, et al., 1978). Valentine's estimate of \$253,000 in damages per miligram per liter is both the highest of the earlier studies, and the most widely used. Using 1974 costs and the Valentine projection, it appears that maintenance of current instream quality is economically inefficient, but that reduction of about 20-40 percent of the additional salt concentration is economically feasible. Using newer data from Andersen (et.al: 1978,



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Figure 3: Marginal Cost and Marginal Benefit of Salinity Control in 1985.

S: Sprinkling and Canal Lining

W: Water Treatment

J: Combination

the 1976 damages have been estimated at approximately \$300,000 per mg/l. The treatment combination (J) appears to be economically efficient in removing all of the increased salinity. However, it is likely that costs have remained constant. Instead, costs of treatment have probably risen at about the same rate as downstream damages, so that the 1-5% reduction is still the relevant range of efficient treatments. Other studies (Andersen, et al., 1978; Utah State University, 1975; Glover, et al., 1979) have also indicated that some sprinkler conversion, canal lining, and selective retirement of saline land is economically efficient as Utah increases its water use toward its compact allocation. These practices are also indicated in some of the Great Basin sub-basins as energy resources are developed.

One question remains, however. While some sprinkler irrigation is economically feasible from the individual farmers perspective irrespective of the salinity problem, canal lining, land retirement and other sprinkler applications are not. The burden of the cost of treatment could be born by upstream users, if treatments were mandated; by downstream users in the form of additional water costs which could be used to subsidize developments; or by the general treasury fund. The distribution of the costs would be a political decision, but, as Coase (1960) has pointed out, the economically efficient solution would be generated in any case, provided the subsidy or burden was of the proper magnitude.

Thus, the water and air quality modeling generated several interesting results.

1. Air quality constraints are currently more restrictive on energy development in Utah than water quality constraints.

2. Energy development may have positive or negative effects on water quality, depending upon whether the source of the water is currently held rights or Utah's unallocated compact share.
3. There exist mitigating treatment practices such as sprinkling, canal lining, and selective retirement which will allow energy and irrigation development and conformity with non-degradation standards. Some of these treatments are economically feasible irrespective of water quality considerations. Others must be mandated or subsidized.
4. Non-degradation standards may be economically inefficient, in that the incremental benefits from maintaining or reducing salinity in the Colorado River Basin are less than the marginal treatment costs which are imposed on the upstream users.

Summary and Conclusions

Results from several Utah State University research projects, using systems analysis indicate that some popular conceptions of problems associated with energy developments may be mistaken. Water scarcity does not appear to be a problem, except in some of the Great Basin drainages, for the foreseeable future. Air and water quality constraints are far more important. Water quality limits, particularly the non-degradation standards, may force a transfer of water from irrigated agriculture to energy users, although there exist mitigating practices which are economically efficient. Strict non-degradation does, however, produce less downstream benefits than upstream costs, at the margin. Some relaxation of the stream standard would appear justified. Air quality standards, as currently imposed, are the only factors which appear to limit energy

development in Utah to less than the resource availability. Whether clean air benefits exceed the foregone returns to energy production is unclear, but the Energy Mobilization Board must eventually evaluate that tradeoff, as well.

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