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ENERGY AND THE COLORADO RIVER*

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It has become common to argue that "water will restrict the development of energy resources in the Colorado River Basin." This argument has four components: (1) Maintenance of streamflow in local reaches of the river; (2) Maintenance of water quality in the local reaches; (3) Shortage of water in the whole river system; and (4) Water quality problems in the Lower Colorado.

SETTING FOR THE PROBLEM

Physical Characteristics[1]

The Colorado River Basin is characterized by the most diverse environmental setting of any river in the United States. High mountainous elevations (over 14,000 feet) are followed by plateaus, sea level plains and low valleys. The water of the Colorado River is the lifeblood of the intermountain area and the southwestern United States. Its drainage covers portions of seven states. The 1440 mile-long Colorado River Basin produces less water per unit area (60 acre feet per square mile) than any other major river basin in the United States. Not only do the 2.5 million people (including the major population centers of Phoenix-Tucson and Las Vegas) within the hydrologic basin depend upon it, but so also do other large major population centers (Denver, Salt Lake City, Los Angeles, and San Diego) of the Colorado River Basin states. The waters of the Colorado directly serve approximately 15 million people in supplying water for cities, irrigated agriculture, energy production, industry, and mining, and at the same time, support wildlife, recreation, and areas of unparalleled aesthetic value to the nation. As Table 1 shows, while agricultural land area in the basin is small, irrigation is the major consumptive use of water from the Colorado River. Of the water used for municipal and industrial purposes fifty-seven percent is exported for use outside of the hydrologic basin.

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1. Material in this section is based on Utah Water Research Laboratory, *Colorado River: Regional Assessment Study, Part One*, Prepared for National Commission on Water Quality, at 8-9 (1975).

TABLE 1
Summary of Land and Water Use in the Colorado River Basin*

	Land Use[1,2]		*Water Depletions*[3]	
	Million Acres	*% of Basin*	*Thousand Acre Feet*	*% of Total*
Rangeland	95.1	58.3	a	–
Forest	57.4	35.2	a	–
Agriculture				
Irrigated	2.9	1.8	3,636	40
Dry	1.0	0.5	a	
Urban (M&I)	0.9	0.5	255	3
Other	3.2	1.9		
Water Surface	1.4	0.8	(evaporation)	
(Water Export	–	–	5,189[b]	57
(Fish & Wildlife)	–	–	39	–
	163.0	100.0	9,119	100

*[1] Upper Colorado Region State-Federal Inter-Agency Group (PSIAC), *Upper Colorado Region Comprehensive Framework Study,* Appendix VI–Land Resources and Use, Water Resources Council (June, 1971).

[2] Lower Colorado Region State-Federal Inter-Agency Group for PSIAC, *Lower Colorado Region Comprehensive Framework Study,* Appendix VI–Land Resources and Use (June, 1971).

[3] Colorado River Salinity Control Forum, Proposed Water Quality Standards for Salinity Colorado River System (June, 1975).

[a] On-site use of precipitation.

[b] Of this, 4,538,000 acre feet are exported to southern California, of which about 1,000 acre feet are diverted by the Metropolitan Water District of Southern California primarily for M&I use, and the balance to the Imperial Irrigation District and the Coachella County Valley Water District predominantly for irrigation use.

Demands are made upon the river both as a source of water and as a carrier of residuals and byproducts of manmade as well as natural processes. Consequently, over time the quality of the water in the Colorado deteriorated; increasing problems of water use and pollution inputs are further compounded by the relatively small flow of the river in relation to the basin size. Certainly the future ability of the Colorado to sustain present uses is dependent on maintaining qualities of water required for them. As additional demands for use are placed on the river, more concern is expressed for the availability of adequate quantities of water and its quality for downstream users.

Legal Institutional Review

The concept of beneficial use is fundamental in water law philosophy of the west.[2] It is the basis and the limit of the right to use water. The intent is to compel a careful husbandry of water. An

2. W. Hutchins, *Water Rights Laws in the Nineteen Western States,* U.S. Dep't of Agriculture, Misc. Pub. No. 1206, Vol. 1, at 9.

appropriation in excess of the reasonable needs of appropriators is not allowed. Appropriation rights are granted with a definite time limit to place the water into beneficial use. As the law has developed, there have developed certain priorities and preferences in use. In Colorado, if water is insufficient to meet all desired uses, "domestic purposes have the preference over all others and agriculture is preferred to manufacturing."[3] However, compensation must be paid to one who has a previous appropriation. Utah provisions are similar. Arizona has similar provisions except that municipal uses are included as a priority use with domestic; non-domestic uses such as manufacturing may be included in the municipal category.[4] The provisions of the beneficial use and appropriations doctrines in water law impose difficult problems to energy developers because of general low preference in the water rights law and the provisions requiring early application to achieve beneficial use. Most energy projects take years of planning and require significant quantities of water. The long-range commitments are troublesome to state water officers.

The allocation system on the Colorado River operates at four levels: international, interregional, interstate, and intrastate.[5] At the international level the division of water between nations was accomplished in the Mexican Water Treaty of 1944.[6] Mexico was guaranteed an annual amount of 1.5 million acre feet, except in time of extreme shortage. The treaty contained no express provision for water quality, although continued agricultural use of the water in Mexico was clearly contemplated.

At the interregional level, the main provision is the Colorado River compact of 1922. This compact divided the basin states into the Upper Basin and the Lower Basin. The compact assures that at least 75 million acre feet of aggregate flow per ten-year period would reach the Lower Basin at Lee Ferry. In the absence of surplus flow, each basin is required to assume equally the burden of the Mexican Water Treaty.[7]

Interstate allocation of water in the Lower Basin is provided for in the Boulder Canyon Project, October of 1928. The decision in Arizona v. California[8] interpreted the Act as follows:

> Congress decided that a fair division of the first 7,500,000 acre feet of such mainstream waters would give 4,400,000 acre feet to Cali-

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3. *Id.* at 19.
4. *Id.* at 20.
5. *Supra* note 1, at 90.
6. *Id.*
7. *Supra* note 1, at 91.
8. Arizona v. California, 373 U.S. 546, 565 (1963).

fornia, 2,800,000 to Arizona, and 300,000 to Nevada. Arizona and California would each get one-half of any surplus.

The Upper Basin states avoided litigation and reached agreement for apportioning rights to the flow in their part of the basin. The Upper Colorado River Basin Compact of 1948 allots to Arizona 50,000 acre feet per year and the balance of consumptive use is apportioned to Colorado, 51.75 percent; New Mexico, 11.25 percent; Utah, 23 percent; and Wyoming, 14 percent.[9] The gross amount of annual consumptive use allowable in the Upper Basin, against which these percentages apply, has become less than 7.5 million acre feet with the downward revision of estimates of river flow. The Bureau of Reclamation now estimates that water available for Upper Basin use ranges from 5.8 to 6.5 million acre feet.[10] Indian tribal water claims based on the *Winters* doctrine present an additional cloud of uncertainty in that these rights are not lost by nonuse. These rights are largely unquantified and may persist indefinitely. These uses will be charged to the state in which use is made.

Intrastate allocations are based on water rights as gained, recognized, and maintained. The consumptive use is charged against the basin state where use occurs.

Most Upper Basin states have not yet appropriated their full allocations since federally funded projects have been slow to develop. However, several reaches of upper basin tributaries have been fully appropriated. Thus, the problem in Upper Basin energy proposals may be either to change use where a stream reach may be fully appropriated, or in other cases to use unappropriated water. Both of these may, however, have important quantity and quality impacts downstream.

Another interesting legal implication of changes in the use made of water is the concept of appurtenance of an appropriative water right to the land on which the water is used. Generally, this concept applies in the West although, "in most jurisdictions the right may be severed from the land to which it initially becomes appurtenant."[11] Wyoming seems to have the most restrictive laws enforcing the appurtenancy rule.

As can be seen from these brief comments on the legal institutional framework, considerable effort beyond determining the physical and economic feasibility of new uses of water is required to develop a project.

9. Article III(a) Upper Colorado River Compact, signed by the state commissioners October 11, 1948, and given Congressional consent on April 6, 1949, 63 Stat. 31.

10. *Supra* note 1, at 92.

11. *Supra* note 2, at 455.

Economic Considerations

The value of water in the Colorado River Basin is a derived demand. That is, the willingness to pay for water is based on its productivity in various uses. Direct consumption of water (drinking) is a notable exception to this, but major users are primarily for producing something else. As such, water has indirect value. This value can be estimated by imputing shares of the value of the ultimate product to each of the factors of production. Imputation of value to water as a production factor such as in growing crops is well established where water is one of the major components of the input structure. The imputation process is not well developed for industrial uses of water.

Table 2 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*

Water use	*Cost increases for a $200 per acre feet 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%

*J. Clair Batty, unpublished data, Utah State Univ., Logan, Utah (Feb. 1975).

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.[12] Further, municipal users have seldom had to pay more than $100 per acre foot for other than culinary purposes.

From these general considerations we may construct an hypothetical but realistic demand curve for water such as in Figure 1.

The previous table and this graph reveal that industrial uses such as energy are likely to have inelastic demands with respect to price (the quantity of water taken would vary little with a price change), and the agricultural uses would have relatively elastic demands. This leads

12. M. Anderson, J. Andersen, and J. Keith, *The Demand for Agricultural Water in Utah*, PR WG 100-4, Utah Water Research Laboratory (1973).

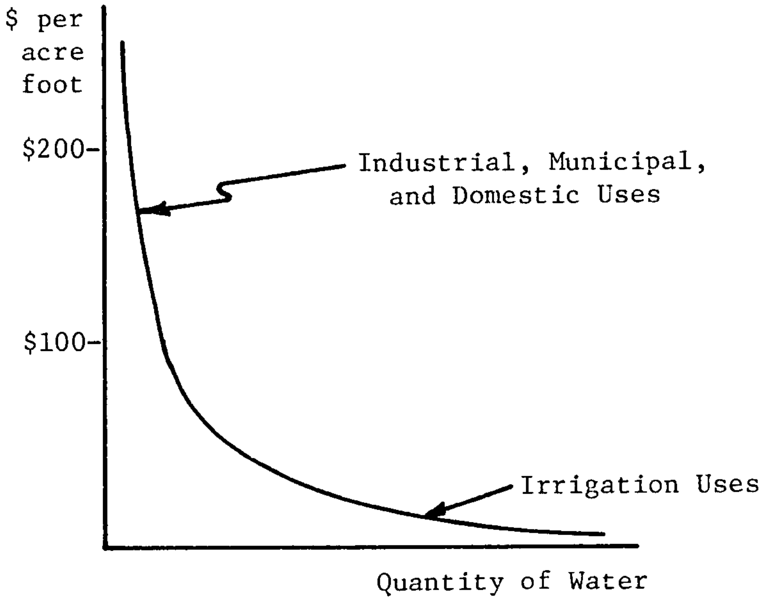

FIGURE 1

Hypothetical Demand for Water in Various Uses

to the rather obvious conclusion that there will be a strong impetus to transfer water from agriculture to other uses to the extent that water would be productive in the other uses.

A second economic consideration is the matter of external effects.[13] Many production processes that result in heavy use of water, including agriculture and energy, produce external effects (externalities) on other water users along a water course. The externalities 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. Therefore, what is optimal for an upstream user may not be so for society, if external effects exist.

The upstream user will press the use of water to the point where he maximizes his own net benefits. External damages do not normally enter the decision framework of an upstream user. The extent

13. This discussion follows B. Gardner and C. Stewart, *Agriculture and Salinity Control in the Colorado River Basin,* 15 NAT. RES. J. 63 (1975).

of such damages is related to two phenomena: (1) water consumptively used upstream cannot be available to downstream users, thus, the concentrating effects of salt in the river downstream will be directly related to upstream consumptive use; and (2) the saline return flows from irrigation or other uses 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*. Thus, the costs imposed on others are bound to increase as the upstream use is increased.

The conclusion is quite clear. Salt concentrations will exceed the social optimum so long as the upstream user's water right permits him to use more units of water than would equate the marginal net benefits he derives to the marginal external damages he imposes. Potentially, at least, the river may yield a greater total economic product if the upstream salt inflow is reduced. This external effects problem has impacts on the local area or on the river as a whole.

Water Demands for Energy Projects in the Colorado River Basin

Proposals for energy development in the Colorado Basin are abundant. They shift and change as the economic and environmental parameters develop over time. Recent developments such as the withdrawal of the Kaiparowitz applications confirm the uncertainties of energy proposals. Thus, the estimates of water uses must have extremely wide confidence bands attached. One estimate is that made in Project Independence as shown in Table 3. These 1985 estimates

TABLE 3

Projected Consumptive Use of Water for Energy in 1985 for the Colorado River Basin*

	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

*Water Resources Coun., *Water Requirements, Availabilities, Constraints, and Recommended Federal Actions, Project Independence Task Force Report to the Federal Energy Administration* (1974).

indicate that a very significant portion of the available Colorado River water may be used for energy production in as few as ten years, if the high levels of development occur. More distant projections are even less certain.

In the Colorado Regional Assessment Study done at Utah State University, the estimate of the increase in water use is as shown in Table 4. These estimates, based on more recent trends and judgments, are much more conservative than those of the Water Resources Council. Nevertheless, they could be substantial factors in the Basin water picture.

TABLE 4

Projected Energy Development Increase by 1990 from Base Year 1974 for Colorado River Basin*

	Production Level Estimate			*Annual Water Use 1000's of acre-ft*		
	Low	*Probable*	*High*	*Low*	*Probable*	*High*
Coal-fired elec. gen. (MW)	19,770	26,350	37,080	243	303	525
Coal gasification (10^6 cf/d)	250	1,785	2,877	0	63	142
Coal slurry pipeline (10^6 ton/yr)	6.2	29.2	32.2	2	20	23
Coal mining (10^6 ton/yr)	113.9	165.8	260.1	4	10	16
Hydro (MW)	503	503	1,903	**	**	**
Nuclear (MW)	2,426	3,810	3,810	50	90	105
Oil shale (thousand barrels)	0	578	1,280	0	68	220
Tar sands (thousand barrels)	0	139	259	0	5	9
				299	599	1040

*_Supra_ note 1 at 57, part two.
**Could vary substantially depending on what fraction of evaporation losses are charged to power production.

Since water rights are generally stated in terms of diversions rather than consumptive use, water rights of at least twice the indicated use may need to be obtained. This may entail a transfer of irrigation water (or at least reduction of rights) if development is on a fully appropriated reach of the river. At present, there are about 1,300,000 acres of irrigated land in the Green River and Upper Main Stem Subbasins. Since more than half of the energy proposals are also in these subbasins, there could be a great impact on irrigated agriculture.

Water Shortages in Specific River Reaches

As noted in the earlier section on economic considerations, there is likely to be a strong impetus to transfer water to energy uses. A man of wide experience in legal and institutional matters in the Colorado River Basin has formulated Moses' Third Law which indicates that "water seeks its own economic level." In more crude terms "water runs uphill to money."[14] The result of this unofficial law is

14. Raphael Moses, *supra* note 1, at 335, part eleven.

that those who are financially able to acquire water from users with a lower-valued use will do so. Cities and industrial users will continue to divert the consumptive uses associated with agricultural rights to their own purposes.

As an example of the effect of energy development on a small reach, the following case is presented. Prior to introduction of a coal-fired electrical generation plant, irrigators had fully appropriated the water rights to the stream. Rights included both direct flow and storage rights in connection with a Bureau of Reclamation project. The water users association had executed a contract through the Water Conservancy District for repayment. The acquisition of water rights by the energy company had the following effects:

1) Approximately 20 percent of the Water Users' Association rights were sold to the energy company at a price of perhaps ten times the average value of water for use in agriculture;
2) Additional storage was constructed by the energy company which provided for a more secure energy water supply and better end-of-season water availability for irrigators;
3) Canal lining and pipes paid for by the energy company reduced water loss and made the irrigation water use more efficient;
4) The repayment to the federal government through the Conservancy District was renegotiated at a much higher level to replace the rate irrigators had been paying, based on their limited ability to repay.

In assessing this situation, it appears to be one in which the movement is towards Pareto optimality (i.e., there are gainers, but no losers). Individual irrigators, power users, and the public at large all seem to be better off in this transaction. As far as the water is concerned, certain consumers of recreation and aesthetics seem to be the only possible losers in this action. But, even here, the additional reservoir and higher minimum flows in certain parts of the channel are at least partially offsetting. In summary, this example of possible water quantity and quality problems in a local reach seems to indicate minimal difficulties.

Water Quality in Specific River Reaches

An interesting development is the tendency of those producing energy to move toward a program of total containment of water. Given the water quality constraints scheduled for imposition in the next few years, the policy reflects an anticipation of problems of effluent discharge and also indicates minor nature of water as a cost factor. The water is recycled until marginal costs of using the successively deteriorated water exceed costs of bringing in more water plus the cost of disposal of spent water in evaporation ponds.

This practice of total containment would generate almost no water quality problems in upper reaches of the river, due to generally high quality water in these areas. To the extent that this non-degradation policy is followed in energy production, local water quality problems will be infrequent.

Water Shortage in the Whole River System

The question of shortages in the whole river hinges almost entirely on the question of whether energy uses replace agricultural uses, or are in addition to them. Table 5 indicates the results of a model of the river in which various scenarios of river flow and water use for key years were assumed. The point on the river at which flows are estimated is the compact point, so that only Upper Colorado options are considered. A high rate of utilization for all purposes combined with a low water yield would create serious problems. A moderate rate of development with a higher river flow would minimize expected problems. Total containment technology would accentuate the water quantity problem because of higher total consumption upstream.

TABLE 5

Predicted Effects on Flows at Lee Ferry of Various Use Scenarios in the Upper Colorado River Basin*

Assumed Flow (Million acre-ft/yr)		*Utilization Level*		*Flows at Lee Ferry (Million acre-ft/yr)*		
	Agric.	*Energy*	*Export*	*1977*	*1983*	*1990*
14	Medium	Medium	Medium	10.5	9.9	9.2
14	High	Medium	Medium	10.5	10.0	9.2
14	Medium	High	Medium	10.5	9.8	8.7
14	Medium	Medium	High	10.4	9.8	9.1
14	High	High	High	10.3	9.6	8.3
12	High	High	High	8.7	8.0	6.7

**Supra* note 1 at 153, part one.

THE WATER QUALITY PROBLEM FOR THE WHOLE RIVER

There are two parts to the quality problem. As mentioned previously, the measurement may be salt load, which is the total quantity of salt flowing down the river in a dissolved state. Or, the measurement may be concentration, which indicates the proportion of salt to a given amount of water. Each of these may be important depending on the particular concern in the downstream area.

In the river modeling study mentioned earlier, the results suggest that as energy development proceeds through time the total tons of salt load would decrease relative to the base situation.

As can be seen in Table 6 the salt load would be decidedly higher with low and medium utilization levels which would lead to greater flows. The salt load would be small under high utilization and low flow.

At the same time, salt concentration in the river would rise with accelerated energy development. The conclusion is that an increased rate of energy development would result in an increase in concentration at Imperial Dam (Table 6). This effect is due to the reduced flows of water for dilution particularly due to the anticipated total containment technology.

The highest concentration problems will arise with low flow and high utilization. Note, however, the small salt load associated with the minimal river flow.

In summary, it seems that energy development *per se* is not the most critical element in the water quality problem. Natural flow rate and the combination of other factors is of more importance.

CONCLUSIONS

It appears that energy *may* have significant impacts on local and regional water allocations and quality. Upon whom the impacts fall will depend to a great extent on institutional and economic constraints and incentives which are imposed, either as a result of historical development or future policy directions. It is not so clear that energy development will be a detriment to either upstream or downstream users of the Colorado River.

Investigations of the problem have lacked depth and broad perspective in many cases. The case of the total containment technology being represented to solve salinity problems is an example. If only one side (in this case the salt load) is considered the answer to the problem may be different than if other factors are brought to bear, such as having water for dilution and extra costs incurred. We suggest a strong, objective look at the social, economic, and physical problems as they can be anticipated with less concern for the sensational elements of the planning process.

TABLE 6

Predicted Salinity Effects at Imperial Dam of Alternative Future Uses in the Colorado River Basin*

Assumed Flow (Million acre-ft/yr)	*Utilization Level*			*Salt Load (Million tons/yr)*			*Salt Concentration (mg/l)*		
	Agric.	*Energy*	*Export*	*1977*	*1983*	*1990-2000*	*1977*	*1983*	*1990-2000*
14	Medium	Medium	Medium	916	912	784	828	922	1090
14	High	Medium	Medium	927	920	790	844	956	1162
14	Medium	High	Medium	916	905	755	828	928	1142
14	Medium	Medium	High	872	875	780	839	937	1097
14	High	High	High	878	880	742	856	977	1235
14	Low	Low	Low	930	938	808	822	890	1011
12	High	High	High	773	762	610	951	1105	1615

**Supra* note 1 at 156-58, part one.