

## A GAMING EVALUATION OF COLORADO RIVER DROUGHT MANAGEMENT INSTITUTIONAL OPTIONS<sup>1</sup>

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**ABSTRACT:** Researchers representing each of the Colorado River Basin states as well as the Secretary of the Interior were presented with an interactive computer simulation of a progressively increasing drought and were given the collective opportunity to change the ways in which basin-wide and within-state water management were conducted. The purpose of this "gaming" exercise was to identify rules for managing the Colorado River which are effective in preventing drought-caused damages to basin water users. This water management game was conducted three times, varying the collective choice rules for management of the river yet staying substantially within the current institution for management of the Colorado River known as the "Law of the River." The Law of the River was quite effective in minimizing drought impacts upon consumptive water uses. Additional effective drought-coping measures to protect consumptive uses consisted mostly of intrastate water management improvements which states were able to implement independently. The Law of the River did not protect non-consumptive water uses, such as hydroelectric power generation, water-based recreation, endangered species, and water quality from drought, as well as it protected consumptive water uses. Players reached collective choice decisions to cope with rising salinity, equalize storage between the upper and lower basins, and protect endangered species. While these measures had some success, only reductions in withdrawals for consumptive uses, particularly in the upper basin, could have substantially lessened adverse impacts.

(KEY TERMS: institutions; gaming; drought; simulation; water management; water policy; Colorado River Basin.)

### INTRODUCTION

Institutional analysts often distinguish three different levels of decision making and action in any public choice situation. They are the operational, collective, and constitutional choice levels (Ostrom, 1986). Action which occurs at each of these levels does so subject to rules which govern the behavior of participants. Such rules also are designated as operational, collective, and constitutional choice rules.

Resource allocation and management occurs at the operational choice level. In the case of a severe sustained drought in the Colorado River Basin, the relevant actions are those of the seven basin states (Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming) and the federal government in operating the water storage and diversion facilities, and this makes the Colorado River the most highly regulated river in the world. Such actions are taken pursuant to the operational choice rules, which in this case have come to be known as the "Law of the River." Examples of parts of the Law of the River that have spawned operational choice rules are the Upper Colorado River Basin Compact of 1948 and the Colorado River Compact of 1922, the Endangered Species Act and the Clean Water Act, the 1964 Supreme Court decree in *Arizona vs. California*, and the operating criteria established for the operation of Glen Canyon and Hoover Dams, which are followed by the Department of the Interior.

Operational choice rules are made and changed at the next higher level of decision making, the collective choice level. Action at this level is concerned only with the making of operational choice rules. Examples of actions taken at the collective choice level include the formulation by the seven states of the Colorado River Compact in 1922, Congressional passage in 1928 of the Boulder Canyon Project Act, and the Supreme Court decision in 1963 in *Arizona v. California*. These actions have been taken pursuant to collective choice rules which determine how the process of interdependent decision making about rules must be conducted. Collective choice rule changes are made within the framework of the next higher level of decision, the constitutional choice level. Constitutional choice rules

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include rules established by the U.S. Constitution, court interpretations, and procedural rules of Congress and the executive branch.

Gaming is one tool used in order to simulate the process of changing operational choice rules. Gaming is the technique of placing subjects in an environment which requires them to make joint or collective decisions among hypothetical options, the prospective consequences of which are shown to them as their interaction proceeds. Repeated "plays" of these games, under differing scenarios, allow subjects to explore the likely impacts or consequences of their collective options by playing "what if?" games. Studies have shown that it is usually possible to discover options which can perform substantially better than existing operating rules in coping with drought or other system-wide problems (Sheer *et. al.*, 1989). Gaming participants can evaluate their alternatives at far less cost, whether in time, money, or other resources, by gaming than by trying out these options in a real setting. Furthermore, repeated trials enable otherwise irreversible mistakes to be discovered within the gaming environment and avoided outside of it.

When conducting gaming exercises, players can carefully specify the collective decision rules in order to allow evaluation of current or proposed institutions. It is then possible to see which of these collective choice rule sets leads to the adoption and implementation of the "best" sets of operating rules (as measured by the consequences of adopting and implementing them). In this way, gaming can be used to discover superior rule sets (institutions) at both the operating and collective choice levels.

In this study, three combinations of collective choice decision rules and information availability conditions, each corresponding to the current and two proposed forms of the Law of the River, were used to conduct a gaming exercise for management of the Colorado River. Two different types of operational rule changes were allowed. Intrastate operational rule changes were used to simulate independent decisions made within each state to manage Colorado River water. Interstate operational rules were used to identify actions that states could take collectively to manage the river. The gaming exercise was then conducted using an interactive computer model to identify superior sets of operational level rules for management of the Colorado River in the event of a severe sustained drought.

## METHOD

We constructed a drought game by modeling the hydrology, water management facilities, institutions,

and economies of the Colorado River Basin by using an interactive simulation modeling tool (STELLA II, tm High Performance Systems, Inc.). The resulting model, called AZCOL, was used to simulate a severe sustained drought and to offer gaming participants the opportunity to manage this hypothetical drought, as it unfolded before them, by changing the operating rules for the system.

The AZCOL model of the Colorado River Basin was constructed specifically to facilitate the gaming exercise, and it relies heavily upon models and methods developed by others on the Severe Sustained Drought (SSD) research team. Representation of basin hydrology, of management facilities, and of current operating rules follows The Colorado River Model (Harding, 1994), while estimation of benefits from Colorado River water use and salinity damages is based upon CRIM (Booker, 1994). Environmental impact indicators were developed by Hardy (1994).

AZCOL is an annual model of the basic hydrology of the basin, with twelve withdrawal points, at least one for each of the seven states which use Colorado River water. Allocation of the river is governed by the operating rules for storage and delivery of water. The priorities and operating criteria which make up these rules are incorporated into AZCOL by using basic logic statements to govern reservoir operations and withdrawal. AZCOL also models salinity throughout the basin, evaluates the dollar benefits from the use of Colorado River water in each state along with hydropower and recreational benefits, and provides general indicators of the condition of environmental resource elements, such as threatened and endangered species (for a more complete description of AZCOL, see Appendix I of Lord *et. al.*, 1994).

The drought employed for the games was the most severe sustained drought which tree ring researchers have been able to reconstruct from historic data. The same drought sequence was run in each of the three games in order to maintain the consistency in severity of drought across games and comparability between games [see Tarboton (1995) and Harding *et. al.* (1995), for details on the drought used and its construction from tree ring records].

The participants played the roles of the seven basin states and the federal government. Each player was a member of the SSD research team. All participants were water resource specialists with detailed knowledge of Colorado River Basin management. In addition, players were assigned to play for a particular state because they had specialized knowledge of the Colorado River management philosophy of that state as well as of the physical Colorado River conditions pertinent to that state. A total of 11 players played the seven states and the Secretary of the Interior (SOI) over the three games. Changes in players were

necessary over the three games because of the length of the games and scheduling conflicts.

Each game was run by allowing pauses in the drought simulation during which players were allowed to make intrastate management decisions and propose and vote on interstate management proposals. Decisions and proposals were allowed in simulation years that were a multiple of five or when the drought reached a major change in system condition. These changes in system condition were called "trigger points" and corresponded to the following water availability conditions on the river: declaration of surplus in the lower basin, shortage in the upper basin, three possible stages of shortage in the lower basin, and a condition where none of the above are true, termed "normal." (For further definition and discussion of the trigger points, see Appendix I.)

Drought impacts were displayed to participants using 1-2 page reports with information for the period of time since the previous decision point in the game. Each player received an individual report containing information pertinent to that particular player's role in the game, as well as a general report with information about basin-wide conditions.

Prior to the gaming, we conducted interviews with what we then believed would be the players in order to elicit their interpretation of the value judgments they believed to be consistent with the water management objectives of states for which they would play. We used the MATS computer program (Brown *et al.*, 1986), developed by the Bureau of Reclamation, to do this. MATS is only one of a number of techniques (ELECTRE and MAUT being others) designed to help decision makers understand their own values and the implications of those values for decision making. In essence, we asked these subjects to trade off economic, environmental, and equity values. We found that, in general, players rated economic impacts as more important than either equity or environmental preservation. However, the value elicitation for the SSD gaming was limited to seven subjects, only six of whom participated in the gaming, leaving five of the participants unrepresented. Therefore, we do not wish to make too much of these results.

More fundamentally, it was not our purpose to impose any set of evaluative criteria upon the decisions made by the subjects. Instead, we attempted to determine what changes in rules for water management they might be able to make in the face of an extreme event, under each of three collective choice rule sets. Such changes, if any, might be good or bad from any of a variety of perspectives. In our conclusions and recommendations, we attempt to critique those decisions from what we believe to be a broadly representative value set, but since eliciting that value

set was not a part of our research, our critique is, accordingly, qualified.

## COLLECTIVE CHOICE RULES

The drought game was played three times, the first time under collective choice rules which correspond to those currently in place, the second time under rules such as those which might characterize an interstate river basin commission, and the third time under rules which permitted water marketing between states. Under the first rule set, modification of the current ways of managing the system required unanimous agreement of all of the basin states and of the Secretary of the Interior, although each of the seven states could make independent decisions about how to manage water within its boundaries. Each of the states operated with whatever information was peculiar to it, together with a limited set of hydrologic information produced by the federal government and made available to all states. This game was played by electronic mail, thus facilitating participation by a geographically disperse group of players and preventing the players from conducting face-to-face and possibly bilateral negotiations.

The interstate compact commission was assumed to produce a broader array of information and to distribute it to all of the member entities so that the information rules changed substantially for the second play, but the aggregation rule of unanimity did not change. The players were assembled in a single location, and the information produced was essentially available to all.

The third play of the game was characterized by these same broadened information rules, but the aggregation rules were changed to permit any two states to decide to lease or sell water between them, although the Secretary of the Interior retained a veto power in order to prevent material injury to third parties. The collective choice rule for interstate operational rule changes not related to water marketing remained in unanimous agreement in the third game. The players were again assembled in the same location. Table 1 summarizes the collective choice rules, plus the operational level rules discussed next.

## OPERATIONAL RULES

Participants in the SSD gaming exercises could choose from two different types of operating rules. They were *intrastate* and *interstate* rule sets. Participants representing any of the seven basin states could

TABLE 1. Summary of Collective Choice Rules and Operational Level Rules.

Collective Choice Rules		
Game	Information Availability	Collective Choice Rule
1. Existing Conditions	Limited	Unanimity
2. River Basin Commission	Extensive	Unanimity
3. Interstate Water Marketing and Water Banking	Extensive	Bilateral Agreement for Interstate Choices 9 and 10, Unanimity for Interstate Choices 1-8
Operational Level Rules		
<b><u>Intrastate Choices - All States Except Arizona</u></b>		
1. Strict prior appropriation		
2. Proportional sharing of water scarcity between agricultural and non-agricultural uses		
3. Intrastate water marketing		
<b><u>Intrastate Choices - Arizona</u></b> (all options include strict enforcement of the Arizona Groundwater Management Act)		
1. No subsidy to agricultural users with CAP contracts		
2. Subsidy for irrigators with CAP contracts to lower the price of CAP water to that of ground water		
3. No subsidy to agricultural users		
Extensive recharge of CAP water into Arizona aquifers		
<b><u>Interstate Choices</u></b>		
1. Uncompensated shorting of Mexican delivery obligation		
2. Compensated shorting of Mexican delivery obligation		
3. Revision of operating criteria for Hoover Dam		
4. Revision of operating criteria for Glen Canyon Dam		
5. Modification of upper basin reservoir operating rules which attempt to maximize power generation at Glen Canyon Dam in the event of a drought		
6. Modification of all reservoir operating rules to meet the requirements of the Endangered Species Act		
7. Implementation of a salinity control program which includes on-farm water-use efficiency improvements and/or control of natural source salt loading, in addition to those programs already in place		
8. Activation of the desalinization plant at Yuma, Arizona to reduce salinity of water delivered to Mexico in compliance with Minute 242 of the International Boundary and Water Commission agreement with Mexico		
9. Interstate water marketing (allowed only in game three)		
10. Interstate water banking (allowed only in game three)		

select from the intrastate options menu unilaterally (without consulting or informing other participants). In other words, they were free to manage water appropriated to their individual states without interacting with other states. Interstate water allocation options could be adopted and implemented only through a collective choice process involving other participants. Individual state participants could propose changes in the intrastate water allocation rules, but they could not adopt, much less implement, such changes unilaterally.

#### *Intrastate Operating Rule Options*

There were three possible intrastate operating rule sets available to each state participant. In all states except Arizona, these options were as follows:

1. Strict prior appropriation, under which available water supplies were delivered to holders of water rights solely according to the seniority of their rights. This was interpreted to mean that agricultural water rights, being generally senior, would be satisfied first. Shortages fall mainly upon municipal users. This option implemented appropriation doctrine but also assumed that water transfers would not occur as a response to scarcity (in reality, the barriers to free transfer of appropriative rights vary significantly among the basin states).

2. Proportional sharing of water scarcity, under which water use cutbacks are imposed upon all water users, without regard to seniority, in the event of supply shortages. This was interpreted to mean that each water user would be shorted by that percentage by which water supplies fell short of aggregate rights. Sacrifices were shared equally by all water users.

Brown *et. al.* (1982) have observed informal arrangements to share adversity among appropriators. Most administrative allocation arrangements, as in the California water districts, impose universal cutbacks, although not always in uniform proportions. Furthermore, Arizona requires increasingly stringent across-the-board reductions in ground water pumping by irrigators and industrial users to meet an eventual goal of attaining safe yield in three active management areas.

3. Water marketing, under which available water supplies were delivered to water users solely according to the marginal value of water in each use. This was interpreted to mean that generally higher-valued municipal demands would be satisfied first, followed by lower-valued agricultural demands. This option did not contradict the doctrine of prior appropriation but coupled it with the assumption that holders of senior water rights whose uses were low-valued (agriculture) could and would sell water to those whose uses were higher-valued (municipalities).

Both Arizona and California rely upon ground water and upon administrative allocation of water supplies much more heavily than do the other basin states. In Arizona in particular, groundwater accounts for over half of annual depletions, and even much of the surface water is allocated administratively by the Salt River Project. Pending disposition of Indian and other federal water rights issues in that state, the appropriation doctrine plays only a minor role in distributing the year-to-year burdens of water scarcity. This, coupled with the great current interest in how Arizona will use and pay for its Central Arizona Project (CAP) entitlement, led to the development of AZSIM (Booker, James F., 1993, unpublished manuscript), a model of Arizona's water economy for use in the SSD analyses, and to the formulation of unique intrastate water allocation options for Arizona to be used in AZCOL. Briefly, those three options are as follows:

1. Strict enforcement of the 1980 Arizona Groundwater Management Act (AGMA) with no subsidy to CAP agriculture. This legislation forbids further depletion (after 2025) of the aquifers underlying the Phoenix and Tucson Active Management Areas (AMAs). Under this option, those two areas rely increasingly upon CAP water, but little CAP water is used by irrigators due to its high cost relative to ground water. CAP use falls below its current levels and rises only slowly thereafter. This option potentially allows Arizona to lease or sell such water to other states.

2. Strict enforcement of AGMA and a similar restriction against ground water overdraft throughout

the entire state, coupled with a subsidy to irrigators with CAP allocations. That subsidy is just sufficient to eliminate the cost difference between using such water and pumping ground water (such a subsidy is currently used in Arizona in the form of tiered CAP water rates for irrigators). Under this option, CAP water use is maximized within the state and the historic overdraft of ground water is ended.

3. Reliance upon recharge and underground storage of CAP water. This option resembles the first strict AGMA option but also includes large-scale recharge of CAP water to the state's aquifers. This water is thus made available, at cost, in years when CAP deliveries may be restricted. The result is that CAP deliveries are increased, compared to option one, and water is stored to meet future exigencies.

### *Interstate Operating Rule Options*

The menu of optional interstate operating rules from which the participants could choose was more detailed, realistic, complex, and open-ended than was that for intrastate rules, as just described. It was the evaluation of these interstate rules which was a main purpose of the SSD research, so they will be described in greater detail than were the intrastate options. These options were identified by the SSD legal and institutional teams as points of institutional flexibility that would likely be tested during the course of a severe sustained drought (see MacDonnell *et. al.*, 1995). Each option was then tested for feasibility by the computer simulation team.

These operating rules were not complete and mutually exclusive options, as were those for intrastate decision making. Instead, they were more in the nature of component elements, which could be assembled in various ways to form complete sets of operating rules:

1. Uncompensated shorting of the Mexican treaty delivery obligation, in which the Secretary of Interior (SOI) decides how much Colorado River water to deliver to Mexico. Resulting savings are divided among states in the sub-basin (upper or lower) where the shortage exists.

2. Compensated shorting of the Mexican treaty delivery obligation, in which water allocation follows the previous rule, but the SOI then decides the amount of the compensation paid to Mexico and the distribution of that cost among the federal government and each of the basin states.

3. Revision of the operating criteria for Hoover Dam which alters the definition of a lower basin shortage and changes the amount by which CAP deliveries will be reduced when this shortage

condition is reached. Currently, a lower basin shortage is declared when the contents of Lake Mead drop below 13,359,000 acre-feet, at which time CAP diversions cannot exceed 800,000 acre-feet annually. Until recently, however, a lower basin shortage was not declared (prospectively, of course, since a lower basin shortage has not yet occurred) until Lake Mead fell below 10,762,000 acre-feet, but at that point CAP deliveries were reduced to no more than 450,000 acre-feet annually. Possible choices for the lower basin shortage declaration level and CAP diversion ceiling are not restricted to those listed above, but these rules should be adjusted in tandem. In other words, subjects could phase in CAP reductions gradually, as in the current rule set, or more abruptly, as in the earlier set. The current rules limit the size of initial cutbacks in Arizona's CAP diversions but raise the probability of such cutbacks, while the earlier rules were designed to maintain the minimum power pool in Lake Mead for as long as possible.

4. Revision of the operating criteria for Glen Canyon Dam, which carry out the required releases to the lower basin under the terms of the 1922 compact and which also strive to maintain hydropower production at Glen Canyon. Currently the Department of the Interior prospectively follows what is called the equalization rule. This rule now requires that 8,230,000 acre-feet (the objective minimum release) be released from Glen Canyon Dam each year, except under three contingencies. The first of those contingencies occurs when Lake Powell is full and inflow exceeds the lower basin delivery obligation of 8,230,000 acre-feet. At that time, water is spilled in sufficient quantities to prevent failure of Glen Canyon Dam. This rule need not concern us here because this contingency would not occur under drought conditions. The second contingency occurs when the contents of Lake Mead fall below those of Lake Powell, at which time releases in excess of 8,230,000 acre-feet are mandated to forestall a possibly needless failure to meet lower basin demands. Because this "equalization rule" is asymmetrical and may even be in violation of the terms of the 1922 compact, an initial option was to abandon it. The third contingency occurs when the sum of the contents of Lake Powell and expected annual inflow is less than 8,230,000 acre-feet, under which conditions the release is limited to the water actually available.

The participants suggested, and eventually adopted, a so-called reverse equalization rule, another option which would maintain the contents of Lake Powell equal to those of Lake Mead by reducing releases from Glen Canyon Dam below the 8,230,000 acre-foot standard whenever Powell was lower than Mead. This, in turn, generated a fourth option, which combined the equalization and reverse equalization rules. Under this rule, Powell and Mead would be

fully equalized, essentially treating them as a single reservoir.

The Colorado River Compact requires that at least 75 million acre-feet be delivered at Lees Ferry in every ten-year period for use by the lower basin states. This is known as the ten-year moving average requirement. It stands in contrast to the fixed annual delivery obligation, called the objective minimum release, which is currently incorporated in the operating rules for Glen Canyon Dam. Our AZCOL model, unlike the Colorado River Model of Harding *et al.*, included the fixed annual delivery obligation rather than the ten-year moving average requirement of the compact. It is virtually certain that the ten-year moving average delivery obligation would be invoked in the event of a severe sustained drought. The adoption by the participants of the reverse equalization rule temporarily suspended adherence to the delivery obligation of the 1922 compact, whether implemented in the objective minimum release rule or the ten-year moving average rule.

5. Modification of the operating rules for upper basin reservoirs, which now attempt to maximize hydropower generation at Glen Canyon Dam. Water is released from these upper basin reservoirs as needed to maintain the minimum power pool in Lake Powell. The optional "store high" rule would maintain the contents of the upper basin reservoirs, subject to required deliveries in satisfaction of releases to the lower basin mandated by the 1922 compact.

6. Modification of the operating rules for all system reservoirs as necessary to meet the requirements of the Endangered Species Act (ESA). We are not aware that such modifications have yet been made. The basic difficulty is that, given adequate scientific knowledge at the time, these reservoirs could not have been built had the ESA been in effect when they were authorized (and had they not been excepted from its provisions). Changes in reservoir operating rules can delay some extinctions, but most of the damage is irreversible, save by removing the reservoirs (and even then, some species may already have been lost).

The optional rule provides that supplemental releases are made from reservoirs, whenever water exists in those reservoirs, in order to preserve endangered species in river reaches to comply with ESA. If activated, these supplemental releases are made to meet minimum stream flows required to maintain endangered species. These minimum stream flows are calculated as percentages of the long-term average flow for the stream reach according to criteria developed by Hardy (1994). In this case, five percent of long-term average flow is used to approximate these requirements.

7. Implementation of salinity control measures in addition to those already employed under United States Department of Agriculture (USDA) and Bureau of Reclamation programs. Options include: (a) reduction of agricultural source loading through on-farm efficiency measures such as lining of irrigation canals, irrigation scheduling, use of more efficient irrigation methods, or land leveling; (b) reduction of agricultural source loading by retirement of agricultural lands currently in production (reduction in agricultural demand); and (c) reduction of natural point and diffuse source loading through interception of saline waters and their disposal or reuse after treatment. USDA and Bureau of Reclamation estimates of costs and potential salt loading reduction are relied upon for implementation of these measures in AZCOL.

8. Utilization of the Yuma Desalting Complex to reduce salinity of Colorado River water reaching Mexico in order to comply with the U.S. obligation to Mexico under Minute 242 of the International Boundary and Water Commission agreement to deliver approximately 1.36 maf of water to Mexico upstream of Morelos Dam with an average annual salinity of no more than 115 parts per million (ppm)  $\pm$  30 ppm over the average annual salinity of Colorado River waters at Imperial Dam in the U.S. Implementation of this option in AZCOL assumes that this facility is complete and that the capacity of the plant is 72 million gallons per day. Stand-by and variable costs of operation are included.

In addition, two interstate options were allowed only in the third game.

9. Interstate water marketing between the upper and lower basins has been discussed extensively in recent years but has not yet occurred. Some believe that there are legal barriers which must be erased for such marketing to occur. Others believe that the barriers are not legal but political. Therefore, water marketing was made an available option only in the third gaming exercise, when collective choice rules were changed from unanimous to bilateral approval. Then, any state could offer to lease some of its (unused) Colorado River water to other states for a stated price. The lease could be for a stated number of years or long-term (greater than the 38-year period considered by the study). A sale occurred only if another state agreed to the terms of the offer and if the Secretary of the Interior (SOI) approved.

10. Interstate water banking is another operating rule change which has been discussed in recent years. It, too, has not yet occurred and may be variously regarded as barred by current rules or potentially available, given sufficient political will. Again, this option was made available only in the third gaming exercise. Under its terms, any state could "deposit"

some or all of its unused Colorado River water in a water bank account for that state, provided that a limit on the total amount of deposits by all states at one time was not exceeded. The water could be withdrawn automatically, whenever the banking state suffered a shortage, or it could be withdrawn on demand, according to instructions from the state. Deposits could not be transferred to another state's account. However, water could be banked by the purchasing state and later withdrawn or offered for sale (or offered before being withdrawn). Similarly, water could be purchased and then banked by the purchasing state. Limits borrowed from the California Water Banking Proposal were placed on the total amount of water a state was allowed to bank during the drought, in order to prevent large-scale negative impacts on non-consumptive values. Those limits are given in Table 2.

TABLE 2. Water Banking Limits on Amounts Transacted (thousands of acre-feet).

State	Quantity
Arizona	1400
California	2200
Colorado	1600
Nevada	200
New Mexico	300
Utah	700
Wyoming	400

## RESULTS

As is shown in Table 3, proposals to change interstate management of the river that were made during the three games can be classified into five broad categories: salinity control, interbasin management of storage, endangered species protection, shorting of deliveries to Mexico, and permanent adjustment of California's basic allocation. Interbasin management of storage refers to proposals to equalize storage in the upper and lower basins by adopting a "reverse equalization" rule or a simple reduction in the required yearly delivery from the upper basin to the lower basin. Proposals in two of these categories — permanent adjustment of California's basic Colorado River allocation and shorting of deliveries to Mexico — were only made in one of the three games.

Salinity control was the focus of game one, in terms of the number of proposals, with six proposals eventually resulting in an agreement on how to apportion



TABLE 3. Nonbilateral Interstate Management Options Proposed.

Type of Proposal	Game 1 (Proposed\Adopted)	Game 2 (Proposed\Adopted)	Game 3 (Proposed\Adopted)
Salinity Control	6\1	0.5\0*	1\1
Interbasin Management of Storage	1\0	5.5\1*	1\1
Endangered Species Protection	3\1	1\1	1\1
Shorting of Mexican Deliveries	2\1		
Permanent Adjustment of California's Basic Allocation		1\0	
<b>Total</b>	<b>12\2</b>	<b>7\2</b>	<b>3\3</b>

\*A reduction in the delivery requirement to the lower basin was proposed in return for upper basin salinity control. This proposal was, therefore, counted as half salinity control, half interbasin management of storage.

costs of a program to cut agricultural salt loading in the upper basin by 10 percent. Endangered species protection was also adopted in this game. In addition, the need for a "reverse equalization" rule was discovered in this game as the contents of Lake Mead stayed unexpectedly high and Lake Powell was drained at a relatively much faster rate. Current operating criteria for Glen Canyon Dam allow forward equalization to equalize the September 30 contents of Lakes Mead and Powell if the contents of Powell are greater than those of Mead. It was discovered that in order to avoid delay onset of upper basin shortages, a reverse equalization rule was needed. This rule was added to the model for games two and three but was not available in game one. A temporary reduction in the yearly delivery requirement from the upper basin to the lower basin was also proposed but required modifications of the model which were possible to complete only in time for games two and three, not game one.

Interbasin management of storage was the focus of the second game, partially as a result of the learning that had occurred in the first game. A reverse equalization rule was adopted after arriving at an agreement to compensate the lower basin if this rule change resulted in the draining of the contents of Mead below the Mead shortage declaration level at a time when the upper basin is unable to make full deliveries to the lower basin. The form of compensation was left unspecified, but if compensation were to be required and no compensation agreement could be reached, the upper basin states would be required to reduce consumption below their present perfected rights (which are, collectively, two million acre-feet). Compensation was not required, however, for the contents of Mead reached the shortage declaration level in years during which the upper basin made full deliveries to the lower basin.

The focus of game three was interstate water banking and water marketing. Bilateral negotiations

between pairs of states were frequent and resulted in seven interstate water transfers and a like number of water banking arrangements, the latter usually but not always associated with water transfers. Every state except Nevada sold Colorado River water to California. Water sold to California totaled 5.8 million acre-feet over the 38 year simulation. Wyoming, Utah, and New Mexico sold water stored in their water bank accounts. Only Colorado used its water banking allotment to defray its shortages. The SOI promulgated additional interstate decisions without protest from the states. These actions included implementation of the reverse equalization rule, protection of endangered species, and utilization of the desalting plant at Yuma, Arizona, to meet international treaty requirements.

There are additional changes which are within the purview of the basin states themselves which were made during these games. The most obvious of these are the water allocation and management rules which the individual states administer within their own borders. Two state players made such changes, which may or may not have required legislative or court action to accomplish (governors in the West have substantial powers to temporarily alter water allocation rules during drought emergencies).

#### *Summary of Drought Impacts by Category of Water Use*

**Consumptive Use Shortages.** The majority of the drought-caused shortages each game occurred in the upper basin. Figure 1 shows yearly shortages as a percentage of requests for withdrawals in the upper basin by drought year for game one – the game in which upper basin shortages were the greatest. In each game, a lower to upper basin call triggered a reduction of consumption in the upper basin from maximum desire for water use to rights. Average

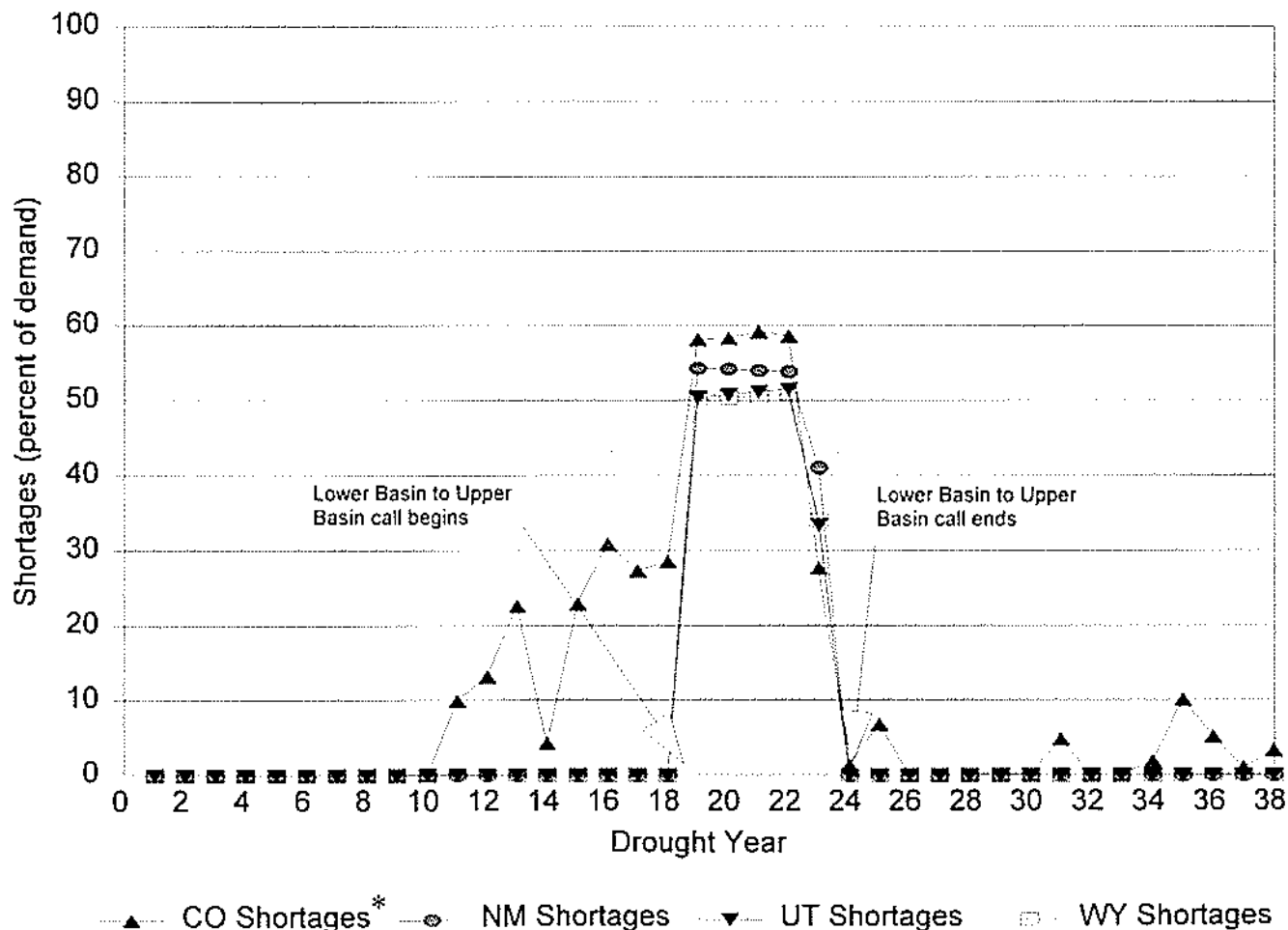


yearly shortages suffered by upper basin states in game one ranged from 52 percent for Colorado to 47 percent for Wyoming. Average shortages were less severe and occurred in fewer years in the second and third games. Average shortages during compact call years ranged from 43 percent for Colorado to 32 percent for Wyoming in game two and from 54 percent in Utah to 46 percent in Wyoming for game three. There were call-induced upper basin shortages for five years in game one, three years in game two, and four years in game three. Reverse equalization rules adopted in games two and three were responsible for reducing the number of years in which a compact call and shortages existed.

The results of each game erroneously showed that shortages in Colorado occurred sooner and lasted longer than in other upper basin states. Colorado shortages which did not occur during the compact call

were a result of excessive aggregation of Colorado demands in the model and do not reflect any real supply limitations. The number of withdrawal points in Colorado has since been expanded from three to five, and sufficient geographic realism has been achieved. However, not enough time was available during the games in order to make these changes. Therefore, during the games, the Colorado player was advised that true Colorado shortages would occur only in years during which a compact call is in effect. The severity of Colorado shortages during years in which a compact call exists is correctly reported by the model.

Shortages in the lower basin occurred in all three games. However, in each case, only the first stage of lower basin shortages was reached – that of reducing the maximum CAP delivery allowed. The degree to which these shortages affected Arizona water users



\* Colorado shortages in years in which a compact call does not exist are a result of excessive aggregation of demands in the model and are to be ignored. Severity of Colorado shortages is correctly represented for years in which a compact call is in effect.

Figure 1. Upper Basin Shortages, Percent of Demand, Game 1.

depended upon the overall intrastate management policy adopted by the Arizona player during the shortages in each game. In game one, Arizona increased its desire for CAP water prior to the onset of lower basin shortages by approving a subsidy of agricultural use of CAP water combined with enforcement of safe-yield ground water use restrictions to all Arizona Active Management Areas. As a result, Arizona suffered average shortages of 0.7 million acre-feet per year over 16 years, compared to its normal maximum CAP allotment, and an average of 0.895 million acre-feet over 21 years compared to the maximum desire for water use under this policy. Arizona adopted different policies in the two other games. In game two, Arizona did not support a subsidy to CAP agriculture and suffered no shortages when its maximum allowable CAP delivery was cut. In game three, also with no subsidy to CAP agriculture, Arizona suffered minor CAP agricultural shortages, averaging 45 thousand acre-feet for four years of the game, only two of which were consecutive. Arizona water users did not suffer any cutbacks in water use in game three, however, for Arizona drew upon recharged CAP water to make up for cutbacks in CAP deliveries.

The other lower basin states besides Arizona did not suffer a drought-caused shortage at any time during the three games. California can be said to be in a chronic state of shortage with a basic allocation of 4.4 million acre feet and a maximum desire for water use around 5.2 million acre-feet. These chronic shortages are independent of the impacts of basin-wide drought and will only be discussed in terms of California's desire for more Colorado River water.

**Hydropower.** Sales from power generated by basin reservoirs remained relatively comparable over the three games. Average yearly benefits from hydropower were almost identical in all games, averaging about \$382 million in each game, or about 70 percent of the highest valued year of hydropower benefits in the simulation. Game three hydropower benefits would have been lower than in the other games had California used more of its banked water, thus draining the contents of Mead below minimum power pool sooner or for a longer duration.

**Recreation.** Monetary benefits from recreation was also very similar across games, ranging from a yearly average of \$349 million in game one to \$342 million in game three, or from 79 percent to 85 percent of the highest valued year of recreation benefits in the respective simulations. Higher benefits from recreation at Lake Mead in game one due to higher lake levels early in the drought sequence accounted for most of the difference across games.

**Salinity Control.** Salinity damages in each game were greatly affected by the salinity management policies adopted. No salinity control measures were agreed upon in game two, resulting in salinity damages of \$52 million in the upper basin and \$188 million in the lower basin. There were also 12 years of the 38-year drought sequence in which Minute 242 was violated. By contrast, in game one, a 10 percent reduction in agricultural salt loading was agreed upon by the players. Compared to game two, the program saved about \$1.47 billion in average yearly salinity damages or \$273 million after subtracting the project cost. In addition, there were four less violations of Minute 242 in game one as compared to game two.

In game three, the desalting plant at Yuma was activated to help meet the obligation to Mexico outlined in Minute 242. The plant was effective in reducing violations of Minute 242, with six less violations than in game two and two less violations than in game one. In addition, the desalting plant reduced the severity of the six violations in game three. However, at an average cost of \$394 per acre-foot of less salty water delivered from the Yuma plant, it is necessary to note that other options such as on-farm reduction of salt loading could be more cost effective in reaching the same result.

**Environmental Attributes.** Environmental specialists on the SSD research team identified seven types of environmental impacts and 16 critical locations for assessment purposes (Hardy, 1994). Impacts were estimated on a four-part ordinal scale. The most severe impact level, in the case of threatened and endangered species, represents extirpation of the species at that location.

Most instances of environmental deterioration are to some degree reversible, but in the case of threatened and endangered species, losses are not so easily reversible. Complete extinction of a species is clearly irreversible, but localized extirpations are probably reversible, given enough time and effort and provided that breeding stocks exist elsewhere in the system.

With an instance of extirpation defined as complete elimination of a single species at a single location in a single year, there were 21 instances of extirpation of threatened or endangered species in game one, 32 in game two, and 30 in game three. These extirpations occurred in Flaming Gorge, Navajo, and Lake Powell reservoirs, and in the Green River below Flaming Gorge. All of the reservoir extirpations were eventually reversed, but that in the Green River was not.

The player representing the Secretary of the Interior invoked the Endangered Species Act to modify reservoir release rules and protect these species in each game. The player in the first game acted to do so

just five years into the drought period. The (different) player who assumed this role in the second and third games waited until the 18th year to do so, which explains the superior record in protecting those species in the first game.

No corresponding special changes in operating rules were made to mitigate environmental impacts other than those upon threatened and endangered species impacts such as wetlands, national wildlife refuges, and native non-listed fish. Consequently, these impacts were negative in 75 percent of the instances. This is so not only because there may be no clear legal basis for mitigating these other impacts but also because there was less understanding on the part of the players (none of whom was an environmental scientist) as to what rule changes might have been effective in doing so.

## EVALUATION AND DISCUSSION

We analyze the results of the three gaming exercises from the perspective of the two purposes for which the exercises were conducted. The first of these purposes was to identify for further study those *operating* options which showed the most promise for mitigating drought impacts and which could be adopted and implemented without Congressional action (new legislation) or additional Supreme Court decisions. We also compare the results of the three gaming exercises, in evaluating alternative *collective choice* institutions. Three such options were investigated, as described previously. These options, unlike those at the operating level, were determined before the gaming occurred and were not within the ability of the players to change. Nonetheless, it is the outcomes of the operating rules which the players selected in each game which permit us to compare and evaluate these collective choice options.

### *Multiple Decision Criteria Exist*

In the SSD gaming exercises, we attempted to display to the players the potential impacts associated with all of the plausible management objectives (water supply, hydroelectric power generation, water-based recreation, water quality control, and environmental preservation) so that each player could give whatever weight he chose to each of them. Although there were differences from state to state and from game to game, each state player was shown about 100 items of information (some of which, like reservoir contents and releases, were not impact measures) for

each year, for a period of no more than five years, at each decision point. The cognitive task for each player was impossibly difficult for decision making within the half hour *de facto* limit which applied. It would be easier for state water managers operating in real time. Still, psychological research has firmly established that the consistency and discrimination of human judgments degrades rapidly as the number of criteria increases.

In the gaming exercises, we chose to present impacts in each category in physical terms and also to display the aggregate monetary impact, as used in the policy capture research. We thus left up to each individual player whether to use the monetary variable or to attempt to trade off a large number of physical impact measures. This was done in part because the monetary variable was so highly aggregated that it obscured possibly relevant distributional considerations and partly because the research team was well aware that water decision makers are traditionally disinclined to maximize net monetary benefits.

The cognitive task of balancing or trading off the five broad management objectives of quantitative water deliveries, hydroelectric power generation, reservoir recreation, water quality control, and environmental preservation is well within the capabilities of human judgment, provided that all of the many detailed impact categories could be satisfactorily aggregated to this level of generality and abstraction and provided that the weights and functional forms of the relevant judgment policy were well known. However, such information is never available, since we are referring to a political process of determining and expressing societal policy objectives, not those of individuals.

### *Decision Criteria are Highly Competitive*

There are many other competitive relationships between water management purposes in the Colorado River Basin. Conflicts between hydropower and recreational and environmental purposes have been prominent recently. Reservoir recreation and whitewater recreation frequently conflict. Reservoir releases for salinity control may conflict with those for power generation. Most obvious of all is the basic conflict between consumptive (water supply) water uses and all of these non-consumptive water uses. And these conflicts between objectives are in addition to the conflicts between states which have characterized the basin for all of this century.

The Law of the River seems to offer clear guidelines to resolving conflicts between competitive purposes and states. To paraphrase, those guidelines state that consumptive water uses must be favored

above nonconsumptive ones, that the lower basin holds rights senior to those of the upper basin, that California rights are senior to Arizona's rights to Central Arizona Project (CAP) water, and that upper basin states share drought risks, in the event of a need for curtailment of use, in proportion to the previous year's distribution of water use between upper basin states. But other rules established since 1922 cloud that conclusion. The Endangered Species Act may supersede the Law of the River if the two conflict, and there has been much speculation and investigation of this possibility in recent years. The Clean Water Act may offer similar possibilities for conflict, although it has received less attention thus far. And the issue of federal reserved rights casts a major cloud over the inviolability of the criteria implicit in the Law of the River. But the seemingly greatest source of conflict, insofar as the results of the SSD gaming has shown, lies in the competitive nature of the technical relationship between consumptive water uses on the one hand and non-consumptive ones on the other. Existing rules, at least those which are formally codified, give little standing to the nonconsumptive purposes of river management. Certainly the players in the SSD drought gaming exercises gave hydropower and recreation short shrift. Lack of attention to hydropower benefits was probably encouraged, however, by our inability to identify state-specific hydropower benefits.

The first and, apparently, foremost decision criterion used by players in the gaming exercises to evaluate operating rules for the Colorado River interstate water management system (hereafter, CRIWMS) was quantitative water deliveries. Historically, each of the basin states has attempted to establish and safeguard its share of the limited quantity of water yielded by the hydrologic system. It is not surprising that the players in the gaming exercise, who were attempting to play the roles of state water decision makers, should focus heavily upon this decision criterion.

### *The Playing Field Is Not Level*

**Consumptive Water Uses Are Well-Protected From Drought.** Figure 2 shows a trace of reservoir contents over each drought game for the two major Colorado River basin reservoirs – Lake Powell and Lake Mead. One role of the substantial storage capacity represented by Lakes Mead and Powell, and by the other system reservoirs, of course, is to mitigate drought impacts by storing water in wet years and delivering it in dry years. Since that storage capacity is large, amounting to about four times the mean annual flow of the river, water uses in the Colorado Basin are well protected against short droughts.

However, the severe sustained drought produced shortages throughout both subbasins and drained Lake Powell to dead storage in all games. Despite these shortages, the system of federal reservoirs, together with the rules under which it is now operated, provide exceptional drought protection to consumptive uses in the lower basin states and good drought protection to such uses in all of the upper basin states.

By far the largest shortages are those suffered by California. But these shortages, which represent California's "surplus" demands (deliveries which are in excess of California's basic entitlement of 4.4 million acre-feet and which are made only in years when sufficient water is available in the lower basin), could hardly be said to be drought-caused, since they occur in each and every year. Upper basin shortages are concentrated in a few years but cause substantial reductions in water deliveries at the depth of the drought.

In year 19, the most severe year of the drought, basin-wide shortages amounted to 12.6 percent of basin-wide water demand, and upper basin shortages amounted to from 50 to 60 percent of upper basin demand. These shortages are considerably lower than some of the shortages which were imposed upon California water users in the last year of the recent (1987-1992) drought in that state. The uneven distribution of drought shortages throughout the basin suggests that institutional changes which distribute those impacts more evenly could reduce hardship at modest cost.

In sum, when seen from the perspective of consumptive water uses, drought-caused shortages were not so large for the basin as a whole as to motivate the players to take heroic measures to mitigate them. Indeed, as will be seen, the results of the three games, played under rather different sets of decision-making rules at the collective choice level, were more remarkable for their similarity than for their differences. There are two plausible explanations for this similarity, the first arising from lack of a significant drought problem and the second from collective choice rules, under all three options, which made changes in operating rules difficult to achieve.

**Nonconsumptive Water Uses Are Highly Vulnerable to Drought.** Nonconsumptive uses are far more vulnerable to drought than are consumptive water uses, at least when the system is managed pursuant to current rules. Figure 3 shows monetary benefits from nonconsumptive and consumptive uses from Game two. Results from Games one and three are virtually identical. Among the nonconsumptive uses, water-based recreation is not as vulnerable to drought as is hydropower generation, which falls to

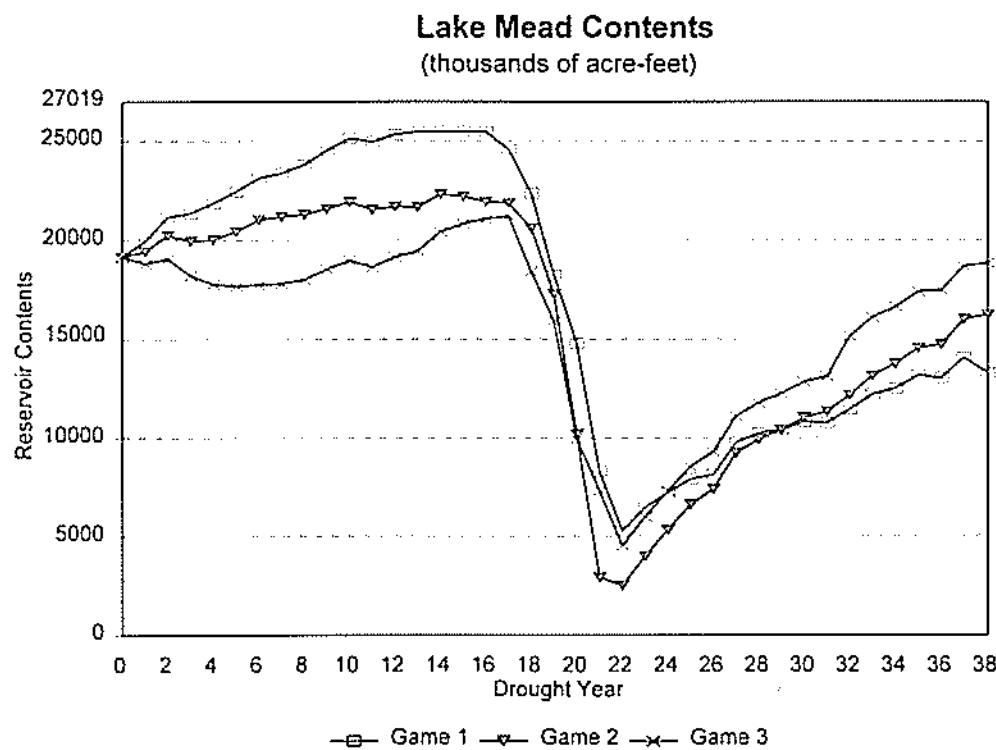
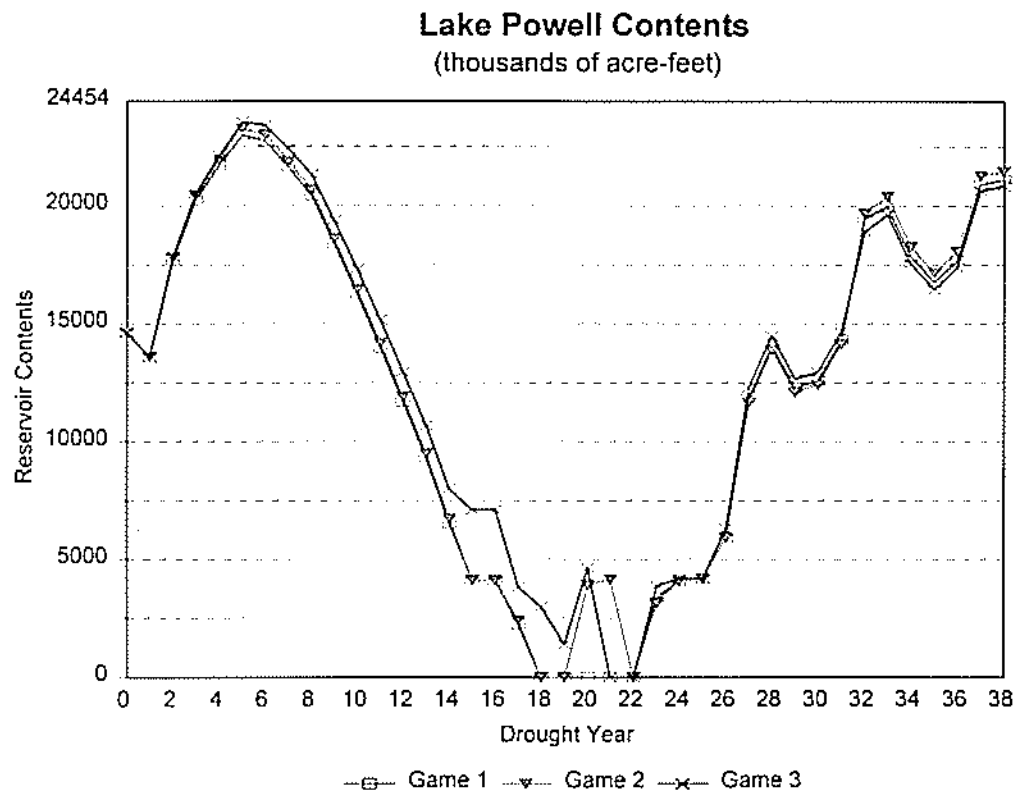


Figure 2. Lake Powell and Lake Mead End-of-Year Contents.

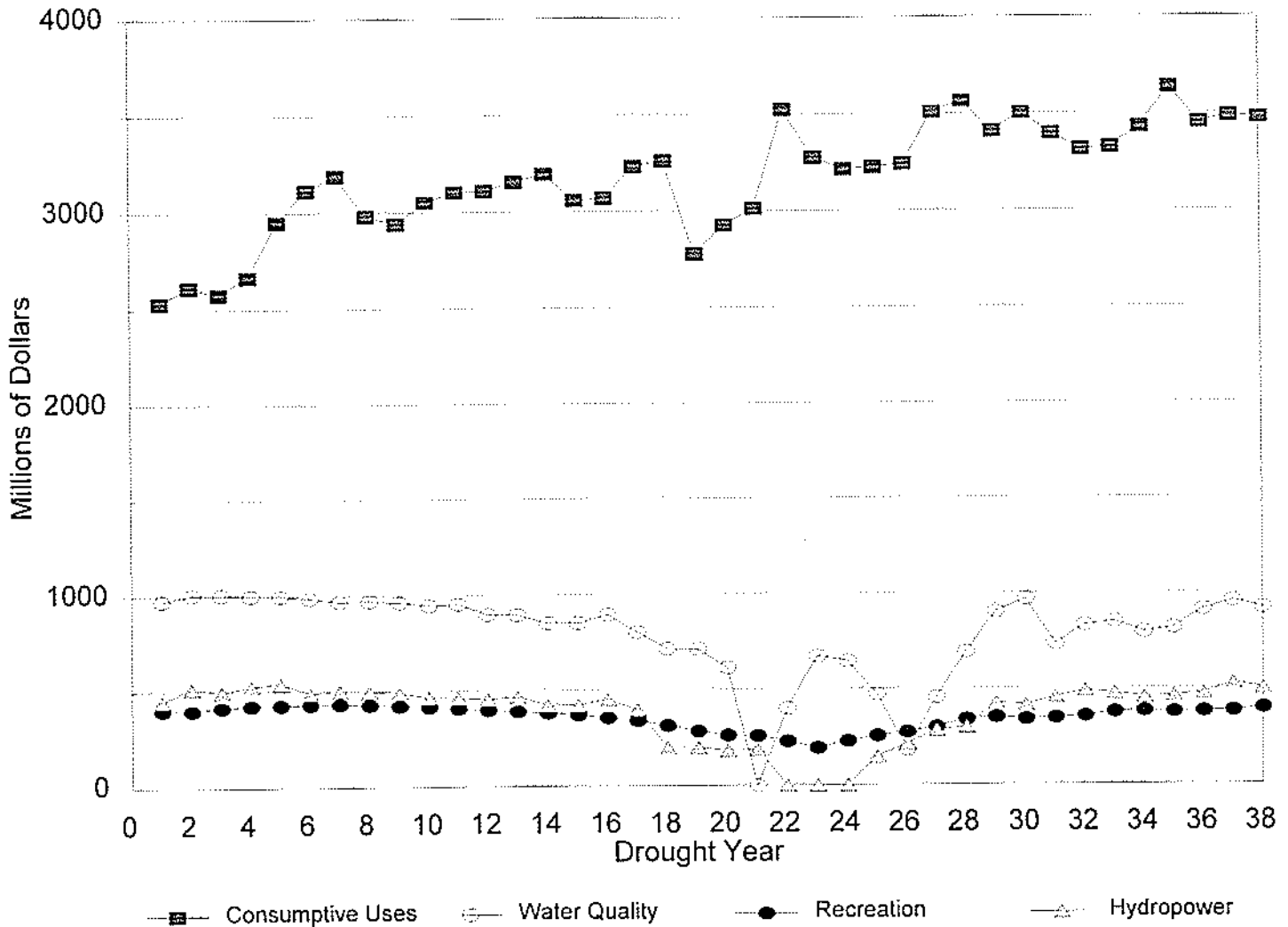


Figure 3. Benefits from Consumptive and Nonconsumptive Uses, Game 2.

zero at the depth of the drought (power is no longer generated when reservoir levels drop below the minimum power pool, even though releases of water can continue to be made). Hydropower was valued conservatively, following Booker *et. al.* (1994). Recreation benefits fall to about half of their normal level at the depth of the drought. Salinity damages rise to at least equal recreational losses.

None of this is to say that drought-caused losses could be avoided through adopting different water management institutions, as was largely possible in the case of consumptive water uses. Because there is less inflow in drought years, there must be less hydropower generation, even if all withdrawals for consumptive uses were to cease. However, by sustaining withdrawals for consumptive uses above levels which would have characterized an unmanaged drought, the Colorado River management system has

increased the severity of drought-related hydropower losses.

A severe sustained drought is likely to cause adverse impacts upon a number of environmental attributes on the Colorado River. Environmental values are not mentioned in the priorities set out in the Law of the River and have not been recognized as a beneficial use in most western states' water codes until recently. Some states have enacted instream flow protection programs, but instream flow rights are usually the junior rights on often heavily appropriated rivers. In addition, the lack of developed markets for environmental attributes means that they are often not included in valuations and decisions made according to a monetary scale. And, because of the public goods nature of environmental values, even if a monetary measure was developed for environmental attributes, it is likely that the monetary value

assigned would underestimate the true societal utility of those attributes.

One way around the problem of the non-market nature of environmental attributes is to develop environmental quality standards according to biological criteria and to identify actions that are appropriate to prevent those values from falling below the criteria. This approach was used in this study, but only for threatened or endangered species protection. The task of identifying what actions would be appropriate to protect all of environmental attributes identified by SSD environmental scientists, which includes wetlands and riparian areas, native nonlisted fish, and national wildlife refuges, is difficult outside of the scope of this study. In each game, players adopted the option that was well identified to protect endangered species – that of maintaining minimum flows in stream reaches with endangered species by using releases from storage reservoirs, if water to do so exists in those reservoirs. In spite of this action, even though the ESA option was implemented early in the first game, there were still at least 21 instances of extirpation of threatened or endangered species in each game.

**Drought Risk is Greatest in the Upper Basin.** The 1922 Colorado River Compact essentially gives the lower basin states seniority in claiming the first 7.5 million acre-feet of Colorado River flows, although it is often held that half of the delivery obligation to Mexico must come out of that allotment. Only after the full lower basin obligation has been met can the upper basin states begin to satisfy their post-1922 demands. Thus, the lower basin has a legal right to at least the first 6.75 million acre-feet of water flowing in the Colorado, after the present perfected rights of approximately two million acre-feet have been satisfied.

On average, the upper basin share may be expected to amount to about 5.5 million acre-feet, including present perfected rights, since the mean annual undepleted flow of the river is now thought to be well below the 16.4 million acre-feet upon which the 1922 compact negotiations were based. Current upper basin withdrawals amount to over four million acre-feet, so the system is nearing the point where demand is equal to supply, even in normal years. Shortages begin to occur at that point, and they are borne disproportionately by the upper basin states.

Again, California could be said to be in a state of chronic water shortage, but it and the other lower basin states are virtually drought-proof. By the 1922 compact agreement, the lower basin gained the assurance of a stable water supply at the expense of limiting its long-term mean withdrawals to less than the amount needed to meet its demands. Conversely, the

upper basin states gained a long-term limitation on the lower basin's share of the system yield, at the cost of assuming almost the entire drought risk of the entire basin. From a drought protection standpoint and considering only consumptive water uses, the lower basin states enjoy a remarkably superior position to that of the upper basin. By the same token, the price paid for that advantage has been high, both in terms of foregoing greater long-term access to normal flows and in terms of impacts upon nonconsumptive water uses (these impacts bear most heavily upon the populous lower basin).

### *Only Minor Changes Can be Made Under Existing Rules*

The most striking aspect of the outcomes of the three SSD drought gaming exercises is their similarity. Upper basin shortages were similar in the first and third games, although they were about one-fourth lower in the second game. They were lower in the second game because the players were able to agree on and implement a reverse equalization rule, which resulted in two fewer years of upper basin shortages. But upper basin shortages rose again (although not greatly) in the third game, despite the adoption of the reverse equalization rule, because some upper basin states sold banked water to California which could have been used to defray shortages.

The decline in lower basin shortages between the first and second games is due to unilateral actions taken by the Arizona player in changing that state's internal water management rules. It does not reflect actions taken at the collective choice level. California's chronic shortages were reduced in the third game as a consequence of that state's purchases of upper basin and Arizona water.

Water banking and water marketing provisions in the third game were heavily used by basin states. However, only Colorado used water banking to stem drought-induced losses. Colorado reduced its game three shortages during the first year of the compact call to 36 percent of maximum desire for water use from 58 percent in the same year of previous games. Had upper basin states other than Colorado also used their banking allotments to defray drought-caused shortages, overall upper basin shortages in game three would still have been substantial but closer to the level of game two.

The observed differences in shortages in the two subbasins between the three games are interesting and not insignificant, but they are very minor changes when seen from the perspective of drought outcomes in general. The players simply were unable to substantially change those outcomes through



negotiating changes in the operating rules. They did, however, employ a very narrow set of decision criteria throughout all of the games. We believe that the players attempted almost single-mindedly to maximize Colorado River water deliveries to their respective states, within and up to the limits of their compact entitlements. The existing operating rules are hard to improve upon, at least for this severe of a drought, from the limited perspective of coming as close as is possible to fulfilling compact entitlements.

Adoption of salinity control measures and endangered species protection were the other operational rule changes that states made an effort to consider in each game. And while adoption of a salinity control program was cost effective in stemming salinity damages in game one and endangered species protection measures were adapted in each game, only reductions in consumptive uses could have significantly reduced damages to these non-consumptive uses.

#### *Intrastate Drought Management is Most Effective*

Two state players, those representing Arizona and Wyoming, were more successful in managing drought, at least by some criteria, than were most others. The Arizona player was able to reduce Arizona's demand for consumptive uses of Colorado River (CAP) water progressively, from 2.5 to under 2 million acre-feet annually over the three games, while at the same time virtually eliminating drought-caused water shortages. In doing so, drought-related monetary losses to Arizona were reduced by \$23 million, on an average annual basis (the reduction was much greater for the worst drought years). The Arizona player's success was due to astute *interstate* water marketing transactions in the third game, coupled with the choice of *intrastate* water management rules which were consistent with interstate water banking and marketing behavior.

The Arizona player began the first game with strict enforcement of the Arizona Groundwater Management Act, which meant that Phoenix and Tucson AMAs were required to meet the safe yield groundwater management goal and thus purchase CAP water to avoid overpumping. Other areas of the state were not so restricted, electing to pump ground water in preference to purchasing the more expensive CAP water. As the drought worsened, however, this player shifted to a state policy which subsidized CAP water use and imposed the safe yield goal on all of the state. As a result, Arizona increased its use of CAP water to its compact entitlement (which reduced deliveries somewhat at the depth of the drought) but incurred financial penalties through subsidizing agricultural uses of CAP water.

The Arizona player, perhaps as a result of learning from the results of the first game, began the second game with yet a different state water management policy than either of those which he had used in the first game. This third policy eliminated the costly agricultural subsidy of the second option and resembled the first policy, except that it employed artificial recharge of all otherwise unused CAP water, also a costly measure. The recharged water was then available during the drought so that Arizona was at least prospectively able to mitigate its drought shortages and adapt to reduced CAP deliveries. In fact, the Arizona player reverted to the first (safe yield) policy half way through the drought period, perhaps in anticipation of relying upon the recharged water at that point, but that stored water was never used because water users could not afford it.

The Arizona player began the third game using the same third (CAP recharge) policy option which he had tried in the second game. However, he quickly reverted to the original (safe yield) policy with which he began the first game, and he remained with that policy for the last 31 years of the drought period. Instead, Arizona became a seller of CAP water to other states which were experiencing drought shortages and was able to profit handsomely without suffering shortages itself.

The Wyoming player in the first game was able to achieve significantly higher water-related net benefits than the (different) player in the third game, despite the fact that Wyoming demand (for consumptive uses), supply (diversions), and shortages were identical in both games. The Wyoming player in the first game also achieved a higher level of benefits than did the (different) player in the second game, even though the player in the second game was able, acting in concert with the other players at the collective choice level, to adopt a reverse equalization rule and thereby reduce upper basin shortages appreciably.

The Wyoming player in the first game selected a change in intrastate water allocation rules which enabled free marketing of water between agriculture and municipalities. The resultant drought-year leases increased benefits to both farmers and municipalities and constituted a more effective drought management strategy, from a monetary perspective at least, than Wyoming was able to achieve through actions taken at the collective choice level in the second game or by interstate water banking and marketing transactions in the third game.

Players who did not adjust their intrastate options seemed to take the general water management philosophies of their states as immutable even in the time of drought. An initial designation of the intrastate option for each state was made by the game controller in accordance with what was believed to

represent the general water management philosophy of each state. The player for Utah in the first game disagreed with a designation for Utah of option one – strict prior appropriation – and made an initial switch to option three, allowing intrastate water marketing. This designation was not changed in the remainder of that game or the other two games. Even when reminded that changes in intrastate option were allowed, players besides those for Arizona and for Wyoming in the first game seemed uninterested in using intrastate management option changes to manage drought impacts.

### SUMMARY

The SSD gaming exercises were conducted within the limited context of those changes in interstate water allocation (operating rules) believed to be attainable without changes in statutes or judicial interpretations. The gaming was conducted under collective choice rules which approximate those currently in effect and then was repeated twice, each time under a modified set of operating rules but, again, including only those changes which were thought to be attainable without legislative or legal action.

One of the principal findings of the gaming exercises was how little difference these changes in collective choice rules made. The operating rules selected by the players were very similar in the three games, and the resultant impacts upon water allocation, management, and use were correspondingly similar. The only really significant difference was that the players were able to modify the existing equalization rule in both the second and third games, thus somewhat easing upper basin shortages at little cost to the lower basin.

A second principal finding was that existing operating rules (and those chosen in the second and third games) favor consumptive water uses over such non-consumptive uses as hydroelectric power generation, environmental protection, salinity control, and recreation. The extent of this favoritism (technically, the tradeoff ratio) is out of all proportion to what are, arguably, the public values involved. This conclusion emerges even when such nonmonetary values as environmental protection are discounted completely. It is even stronger if reasonable weight is given to these nonmarket factors.

A third principal finding is that existing decision-making institutions for interstate water allocation and management are designed to resolve conflicts between states acting exclusively in their own self-interests. They are not designed for discovering what the collective or common interest may be, unless that common interest is taken to comprise only resolution

of such interest conflicts. Still less are they designed to facilitate action in the common interest, should it be revealed.

The fourth principal finding is that the existing operating rules needlessly limit California's long-term water supplies while needlessly increasing the upper basin's vulnerability to short-term drought. It would be relatively inexpensive for the upper basin and Arizona to reduce their long term claims upon Colorado River water in order to enable California to meet demands which already exist. It would be similarly inexpensive for California because of the high priority position in the lower basin of its basic apportionment and the well insulated position of the lower basin relative to the upper basin in the event of a severe sustained drought, to agree to share the burden of accommodating future drought shortages more equally, thus relieving what could be traumatic shortages in upper basin states. This finding reveals a clear opportunity for grasping that most desirable of conflict resolution possibilities, the positive sum solution in which there are only winners and no losers.

### APPENDIX I SYSTEM CONDITION INDICATORS USED AS "TRIGGER POINTS" IN AZCOL

- Surplus:** Declaration of lower basin surplus.
- The contents of Lake Mead plus the projected inflow are greater than the capacity of Lake Mead minus the scheduled deliveries to the lower basin.
- Normal:** No lower basin surplus and no upper basin shortage.
- Mead contents less than capacity.
  - Powell not empty.
- Shortage 1:** There are upper basin shortages but no lower basin shortage.
- Powell empty.
  - Mead greater than lower basin shortage declaration level.
- Shortage 2:** The first stage of lower basin shortages.
- Mead is less than lower basin shortage declaration level. CAP deliveries are reduced to their "shortage" delivery level.

**Shortage 3:** Second stage of lower basin shortages.

- Mead plus inflow not large enough to support full level of CAP "shortage" deliveries. CAP deliveries are further reduced or entirely eliminated.

**Shortage 4:** Third stage of lower basin shortages.

- Mead plus inflow not large enough to satisfy lower basin rights senior to CAP plus Mexican obligation. Proportional reductions rights senior to CAP are instituted.

Shortage 1 represents a situation where a call is placed on the river by the lower basin to the upper basin in order to maintain full deliveries at Lees Ferry from the upper basin to the lower basin, while the contents of Mead remain above the Mead shortage declaration level. In the case of a call, the upper basin states would be required to restrict use of Colorado River water to their rights as determined by the Upper Colorado River Basin Compact. Shortage conditions 2 through 4 may exist without a lower basin to upper basin call. A compact call indicator was used in addition to the shortage stage indicators to allow for this possibility.

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