IMPACTS OF A SEVERE SUSTAINED DROUGHT ON COLORADO RIVER WATER RESOURCES[1]

Benjamin L. Harding, Taiye B. Sangoyomi, and Elizabeth A. Payton[2]

ABSTRACT: The impacts of a severe sustained drought on Colorado River system water resources were investigated by simulating the physical and institutional constraints within the Colorado River Basin and testing the response of the system to different hydrologic scenarios. Simulations using Hydrosphere's Colorado River Model compared a 38-year severe sustained drought derived from 500 years of reconstructed streamflows for the Colorado River basin with a 38-year streamflow trace extracted from the recent historic record. The impacts of the severe drought on streamflows, water allocation, storage, hydropower generation, and salinity were assessed. Estimated deliveries to consumptive uses in the Upper Basin states of Colorado, Utah, Wyoming, New Mexico, and northern Arizona were heavily affected by the severe drought, while the Lower Basin states of California, Nevada, and Arizona suffered only slight shortages. Upper Basin reservoirs and streamflows were also more heavily affected than those in the Lower Basin by the severe drought. System-wide, total hydropower generation was 84 percent less in the drought scenario than in the historical streamflow scenario. Annual, flow-weighted salinity below Lake Mead exceeded 1200 ppm for six years during the deepest portion of the severe drought. The salinity levels in the historical hydrology scenario never exceeded 1100 ppm.
(KEY TERMS: water resources planning; water policy/regulation/ decision making; water management; water law; social and political; irrigation; water quality; simulation; drought.)

INTRODUCTION

In the Colorado River Basin, as in other arid areas of the globe, drought is a frequent phenomenon. Because droughts affect human activities, particularly food and energy production, a variety of measures to cope with droughts have been developed. In the Colorado River Basin, the most conspicuous drought-coping mechanism has been the construction of a complex of reservoirs with an aggregate storage capacity four times the average natural flow of the river. Thus frequent droughts, like those recorded since non-native settlement of the basin, are mitigated by delivery of water held in storage. The system has not been tested by an infrequent severe sustained drought.

Reconstructions of pre-historic streamflows in the basin, based on tree-ring analysis, show that droughts with much more severity than those indicated from historical streamflow records have occurred in the basin's past (Tarboton, 1995). In addition, should global warming occur, it will likely bring more variable precipitation, increased evapotranspiration, and possibly sustained droughts. Hence it is appropriate that, even though severe sustained droughts can be expected to occur infrequently, their effects be quantified.

The objective of this study was to investigate the impacts of such a severe and sustained drought on the hydrologic environment of the Colorado River Basin. The impacts were characterized in terms of streamflows, consumptive use, storage, hydropower generation, and salinity. The effects of the severe drought on these system characteristics were determined with a simulation model of the basin, the Colorado River Model.

PHYSICAL SETTING

The Colorado River basin drains approximately 243,000 square miles contained within the states of Colorado, Wyoming, Utah, New Mexico, Nevada, Arizona, California, and parts of the Mexican states of Baja, California, and Sonora (Figure 1). The basin is divided both geographically and politically at Lee
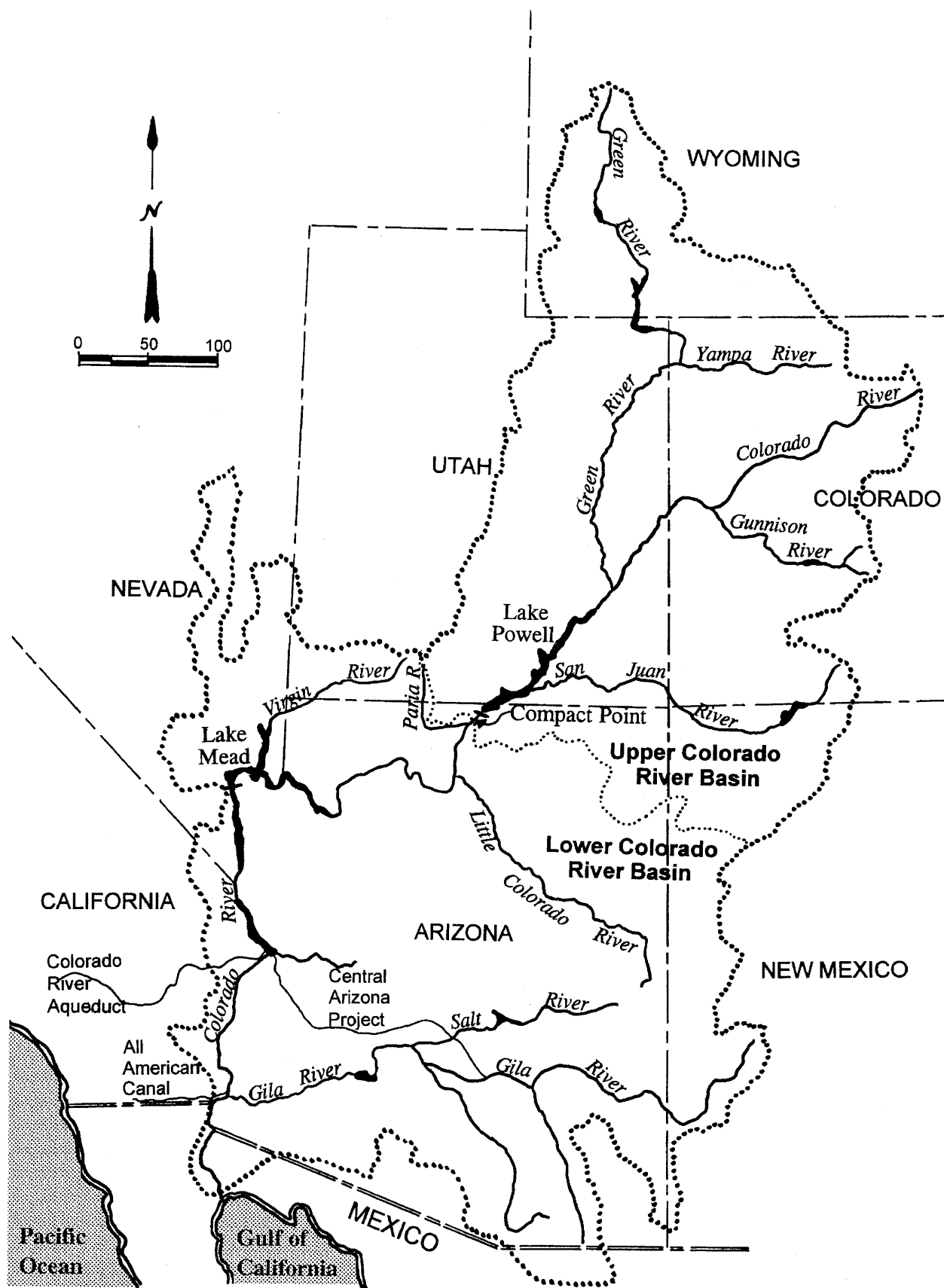
Figure 1. Colorado River Basin.

Ferry, just downstream of the point where the river crosses the Arizona-Utah border. The Upper Basin includes lands in the states of Colorado, New Mexico, Utah, Wyoming, and a small part of Northern Arizona, and is the principal source of inflow into the Colorado River system. The Lower Basin includes lands in the states of Arizona, California, Nevada, and New Mexico.

The natural flows in the basin are highly irregular in occurrence. While the annual natural flow at Lees Ferry, Arizona (the location of a streamflow gaging station, about 1 mile upstream of the Colorado River Compact point at Lee Ferry, Arizona), has averaged 15.2 million acre-feet (maf) over its period of record, flows in excess of 23 maf and less than 7 maf have been recorded. Over 70 percent of the annual natural flow occurs in the months of May, June, and July. Flows have been recorded for less than 100 years at most gaging points on the river.

Many reservoirs alter the natural flow of the Colorado River. The 14 reservoirs modeled in the Colorado River Model contain a total active capacity of 61,375,000 acre-feet. The two principal reservoirs, Lakes Powell and Mead (formed by Glen Canyon and Hoover Dams, respectively), provide over 50 maf of storage. Water is diverted from the river at hundreds of relatively small diversion points in the Upper Basin. The Lower Basin diversions tend to be larger and considerably fewer in number.

The Colorado River is already one of the most fully developed in the world. However, additional storage and diversion projects are being planned and actively pursued throughout the basin. Current water development plans of the individual states generally anticipate full development of their legal entitlements by the year 2060.

INSTITUTIONAL SETTING

The allocation of water within the Colorado River Basin is constrained within an institutional setting which has evolved from judicial, statutory, and administrative decisions collectively known as the Law of the River. These include the Colorado River Compact (1922), the Boulder Canyon Project Act (1929), the California Seven Party Agreement (1931), the Mexican Water Treaty (1944), the Upper Colorado River Basin Compact (1948), the Colorado River Storage Project Act (1956), the Supreme Court Decree in Arizona v. California (1963), the U.S. Army Corps of Engineers' Water Control Manual for Flood Control, water delivery contracts, and the Criteria for Coordinated Long-Range operation of Colorado River Reservoirs (Operating Criteria), among others. Summaries

of the relevant governing law can be found in Meyers (1966) and Nathanson (1978).

THE COLORADO RIVER MODEL

The Colorado River Model simulates the Colorado River system by using a network flow algorithm (Texas Water Development Board, 1972; Clasen, 1968; Barr et al., 1974) to perform, at each time-step, a static optimization of water allocation within a given system of priorities in a river basin network. Various institutional and physical settings are represented by arc connections, constraints, and costs and so may be evaluated by adjusting those parameters. Because water allocation in the basin is driven primarily by institutional rather than economic principles, the optimization capability of the network algorithm is used for efficient simulation and priority-based allocation.

The model has the same temporal and spatial resolution as the U.S. Bureau of Reclamation's (USBR) model of the Colorado River, CRSS (Schuster, 1987; 1988a; 1988b), with certain enhancements. Thus, the model uses a monthly time-step and includes 107 river reaches, 14 basin reservoirs, 29 inflow points, and 265 individual consumptive use points. An earlier generation of the Colorado River Model was used by Brown et al. (1988; 1990) in a study of the disposition of streamflow increases from the Arapaho National Forest.

System processes simulated in the model include most processes generic to any large river basin, such as water allocation, reservoir operations, evaporation, hydropower generation, and salinity. The model also simulates operations specific to the Colorado River Basin and the Law of the River including flood control releases, an objective minimum release from Lake Powell of 8.23 maf per year, inflow forecasting, calculation of the Section 602(a) storage criterion, equalization between Lakes Powell and Mead, the Colorado River Compact requirement of a 75 maf, 10-year moving total minimum delivery at Lee Ferry, and the declaration and quantification of shortages and surpluses in the Colorado River Basin (Hydrosphere's Colorado River Model Technical Overview, 1994).

SYSTEM SIMULATIONS

Two simulations of the Colorado River were made: one assuming the occurrence of a 38-year severe sustained drought cycle and a second assuming a 38-year period of inflows representative of historical

conditions. The two simulations used the same assumptions regarding operational protocols, demands for consumptive use of water, and initial conditions.

Initial Conditions

System starting conditions are set by initializing reservoir starting contents and salinity levels. Starting contents were set to reported storage on October 1, 1991. Capacities and starting contents for the system reservoirs are shown in Table 1.

TABLE 1. Reservoir Initial Conditions
(thousands of acre feet).

Reservoir	Active Capacity	Starting Contents
Fontenelle	345	267
Flaming Gorge	3,724	3,194
Starvation	255	255
Taylor Park	106	89
Blue Mesa	830	669
Morrow Point	117	117
Crystal	18	17
Navajo	1,642	1,635
Powell	24,454	14,654
Mead	27,019	19,200
Mojave	1,810	1,371
Havasu	619	557
McPhee	381	381
Ridgway	55	55

Inflow Hydrology

Two inflow sets were used for this study, a historical set and a severe sustained drought set. An inflow set consists of monthly time-series inflow data for 29 locations throughout the Colorado River Basin. The monthly values represent headwater flows on the mainstem and on major tributaries like the Green, Gunnison, San Juan, and Duchesne Rivers as well as gains along major tributaries or along the mainstem. For the most part, the inflow data are natural flows; that is, they represent unregulated, unimpaired streamflows. Some of the inflow data are gaged flows and hence reflect upstream regulation. The results of the model runs are expressed as simulated flows and also reflect upstream operations, including diversions, storage, and releases from storage. The two inflow hydrology sets used for this study, the historical

streamflow set and the severe drought set, are described below.

Historical Streamflow Hydrology. The inflows used to represent the "normal" hydrology are for the 38-year period from October of 1938 through September of 1975. This period was selected because the average annual flow at Lees Ferry from 1938 through 1975 is equal to the median value of the average flows at Lees Ferry (14.1 maf) over the 41 38-year periods in the period of record (1906-1983). The larger set of historical inflows, from 1906-1983, were developed by the USBR for input to the CRSS model. Most of the Upper Basin inflows in the historical data set are natural flows. The Lower Basin inflows which represent tributaries, like the Bill Williams, are actual gaged flows or estimates of gaged flows. The Lower Basin inflows that represent gains are natural flows calculated by backing out upstream operations.

Severe Sustained Drought Hydrology. Derivation of the severe and sustained drought inflow set is described in Tarboton (1995). The period selected for analysis was 1579 to 1600. This 22-year period was found to contain the most severe drought in over 500 consecutive years of reconstructed streamflows. The annual flows in this period were rearranged to produce a drought of exceptional severity and were appended with originally-ordered reconstructed streamflows (1601-1616), to create a 38-year inflow data set which contained both the drought and a recovery period. This inflow configuration was adopted to represent a severe sustained drought in this and other project analyses.

The mean of the 38-year severe drought streamflow at Lees Ferry is 12.68 maf, and the mean of the 38-year historical trace is 14.1 maf. The drought streamflow trace begins with a total annual flow at Lees Ferry of 12.74 maf in the first year, jumps to 17.23 maf in the second year, and thereafter declines until it drops to its lowest level of 4.57 maf in year 21. The system starts to recover from the drought condition in year 22. The average streamflow of the severe drought trace over the first 21 years of the study period is 11.09 maf. A hydrograph and other characteristics of the severe drought are presented by Tarboton (1995).

Depletions

Water demands in the Colorado River Model are simulated as "depletions," the amount of water delivered for use minus the amount of water that returns to the river after use. Total depletions increase over the 38-year period of the simulations, beginning with

estimates of actual water use for 1992 and progress-ing to projected values for subsequent years. Three levels of projected future depletions – referred to as low, medium, and high – were developed for use in the Severe Sustained Drought Project (Booker, 1995). The medium level was used for the study reported in this paper. The depletion estimates were, for the most part, derived from data developed by the USBR for its 1991 Annual Operating Plan, dated July 22, 1991. This depletion level assumes demand growth is repre-sented by the USBR schedule for years 1992 to 2030, but with agricultural uses fixed at 1992 levels. The Las Vegas, Nevada, depletion is assumed to grow with projected population increases. The Central Arizona Project (CAP) depletion fluctuates over the study peri-od, according to a schedule developed in the gaming exercises described by Henderson and Lord (1995).

The USBR depletion estimates on which the deple-tion data for this analysis are based were developed through model studies that included consideration of water supply, legal entitlement, current and expected delivery capacity, and expected development of water-using projects. Thus, they cannot be considered econo-metric estimates of demand for water.

RESULTS

Depletions

The simulations show that a severe sustained drought would heavily affect the Upper Basin states (Colorado, Nevada, New Mexico and Utah) but would have little impact on water use in the Lower Basin states (Arizona, California, and Nevada) for the pro-jected depletion levels assumed. Results indicate that the Upper Basin states would experience a depletion shortfall of almost 59 percent in the worst drought year of the severe drought scenario. In contrast, the Lower Basin states would experience a depletion shortfall of about 3 percent of their basic entitlements in the worst drought year. Under a severe drought, all of the Lower Basin shortages would occur in Arizona and Nevada. California depletions would not be reduced below their basic entitlements; however, the Metropolitan Water District of Southern California (MWD), which serves the Los Angeles metropolitan area, would be deprived of surplus deliveries which would be available to it under historical streamflows. Water deliveries to Mexico would not be reduced below the 1.5 maf per year entitlement under a severe drought, though surplus deliveries to Mexico would be less than under historical streamflows. Deliveries to consumptive uses in the Upper and Lower Basins, under the severe drought and historical streamflow scenarios, are summarized in Table 2.

The minimum depletions for the Lower Basin states are the same under the severe drought scenario as under the historical scenario because the minimum demand for water, at the start of the study period, was lower than even the shorted deliveries later in the simulations. Upper Basin depletion shortfalls occurred in eight years of the 38-year study period in the drought scenario. Approximately 2.0 maf of Upper Basin depletions are present perfected rights; that is, their water rights were perfected prior to June 15, 1929, the date of enactment of the Boulder Canyon Project Act and therefore are not subject to calls for water under the Colorado River Compact. Under the severe drought scenario, even the present perfected rights suffered shortfalls in the two worst drought years because of local water supply deficits. In con-trast, there were only two years in which depletion shortfalls to the Lower Basin occurred under the

TABLE 2. Annual Depletions in the Colorado River Basin (thousands of acre feet).

Region	Severe Drought			Historical Streamflows		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Upper Basin	1,809	4,632	3,999	3,887	4,632	4,304
Lower Basin						
Arizona	1,782	2,566	1,894	1,782	2,776	2,004
California	4,389	4,984	4,419	4,389	5,101	4,485
Nevada	201	264	243	201	264	243
Total Lower Basin	6,372	7,814	6,556	6,372	8,141	6,732
Mexico	1,516	1,516	1,516	1,516	3,202	1,671

drought scenario, years 22 and 23, when the active contents of Lake Mead dropped below the shortage level of 10.762 maf, prompting a shortage declaration. When a shortage is declared, deliveries to CAP are curtailed to the minimum annual delivery of 450,000 acre feet, and a shortage equal to 4 percent of the CAP curtailment is imposed on Nevada. California's normal entitlement depletions were not affected in any year during the study period, though surplus deliveries to California were 69 percent less, on average, under the drought than under the historical streamflows. Surplus declarations were made twice, in years 6 and 7, of the drought scenario and were taken by California and Arizona. In the historical scenario, surplus declarations were made in eight of the 38 years.

Streamflows

The simulations showed that a severe sustained drought would lead to an average monthly streamflow reduction of up to 12 percent at some locations, when compared to historical streamflow conditions. Table 3 below contains a summary of the streamflows at nine locations in the basin for the two scenarios.

With the exception of streamflows at the San Juan River confluence, the average monthly streamflows were lower under the drought scenario than under the historical scenario for all of the streamflow locations listed. The reduction in average streamflows ranges from 6 to 12 percent. The minimum flow for some stream reaches is zero because no minimum streamflow requirements were assumed for these simulations; therefore, in some months, the entire flow went to storage or was depleted to meet consumptive use requests.

The natural and simulated annual flows at Lee Ferry under the two scenarios are shown in Figure 2. Except for minor inflows from the Paria River, the simulated streamflows at Lee Ferry reflect releases from Lake Powell. In the historical streamflow scenario, the annual simulated flow at Lee Ferry did not drop below the 8.23 maf objective release throughout the 38-year study period and actually exceeded 9.0 maf in 11 years of the 38-year study period. Releases above the 8.23 maf objective were made to equalize the contents of Lakes Powell and Mead as provided for in the Operating Criteria. There were also six years in which at least some water spilled from Lake Powell.

In contrast, the total annual flow at Lee Ferry for the severe drought scenario dropped below the annual objective release level in 4 years of the 38-year study period. The total annual flow at Lee Ferry was 4.61, 4.55, 2.97, and 5.08 maf in years 19, 20, 21, and 22, respectively, as the drought intensified. A Colorado River Compact call occurred in year 21 when the 10-year moving total at Lee Ferry dropped below 75 maf. However, a release required to bring the 10-year total up to the 75 maf level could not be made in year 21 because inflows and reservoir storage in the Upper Basin were not enough to satisfy both the Compact call and the present perfected rights. Only 2.97 maf could be delivered in year 21 from the Upper Basin, and those flows occurred only in months in which Upper Basin inflows exceeded the consumptive use requests of the present perfected rights. The 75 maf moving total delivery requirement was not met again until year 26, four years after the system had started to recover from the severe drought.

TABLE 3. Monthly Streamflow at Selected Points in the Colorado River Basin (thousands of acre feet).

| Region	Severe Drought			Historical Streamflows		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Green River Below Fontenelle	8	626	94	8	640	100
Green River Below Flaming Gorge	0	810	104	0	761	108
Yampa River Above Green Confluence	0	773	104	0	812	116
White River Above Green Confluence	0	193	36	0	209	38
Gunnison River Below Curecanti	2	719	128	15	746	143
San Juan River Above Colorado Confluence	0	822	101	0	1,207	96
Colorado River Above Powell	20	3,944	704	82	4,225	764
Colorado River at Lees Ferry	2	2,043	687	309	2,321	741
Colorado River Below Mead	245	1,006	661	296	1,666	702
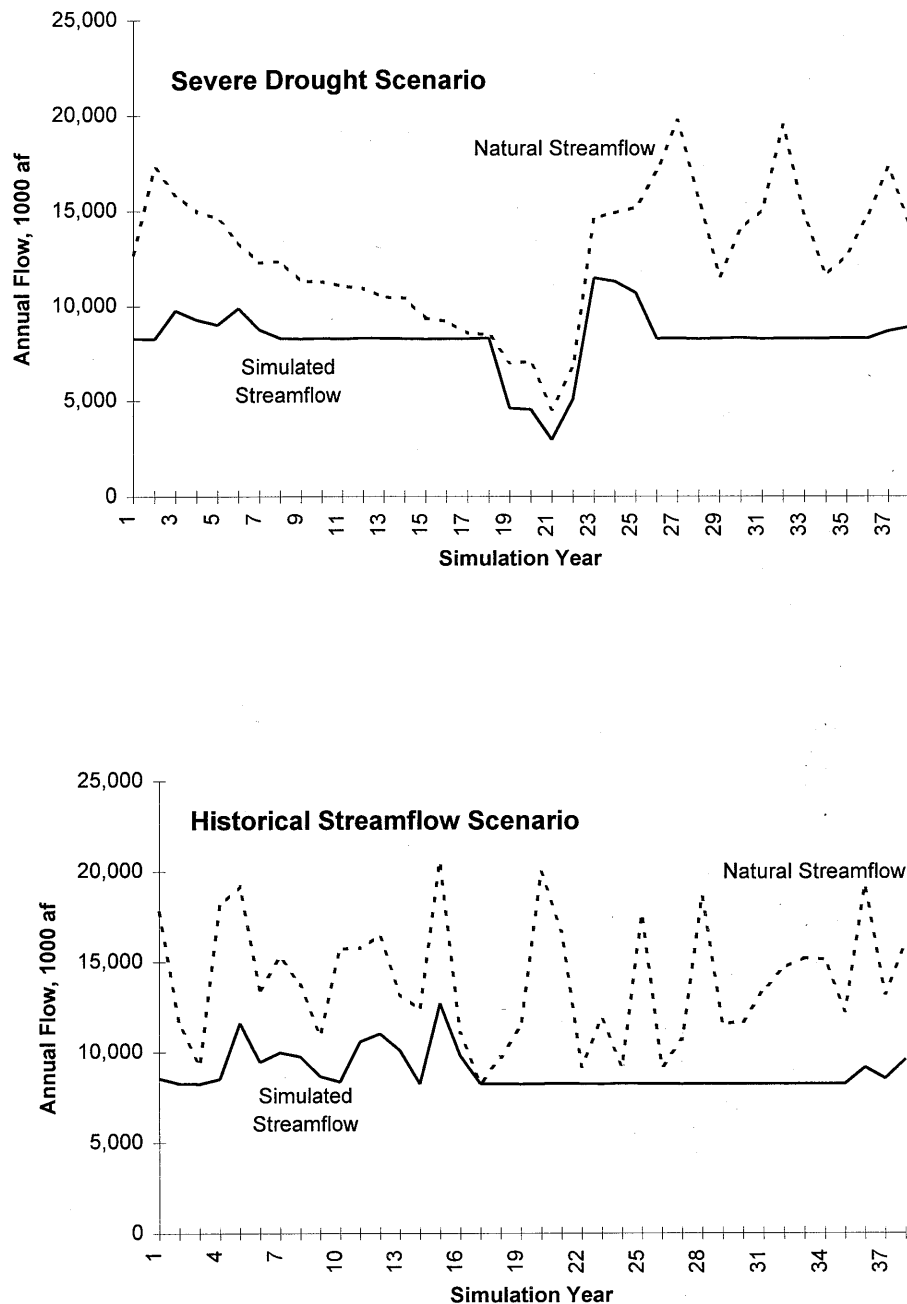
Figure 2. Annual Natural and Simulated Flows at Lee Ferry, Arizona.

Reservoir Contents

Storage in Upper Basin reservoirs, including Lake Powell, would decline to dead storage levels during the worst years of a severe sustained drought. This is in sharp contrast to reservoir contents in the Lower Basin, which would still have water in active storage during the worst drought years (Figure 3). The marked difference between storage in the Upper and Lower Basin reservoirs is a result of water being

released from the Upper Basin to meet the objective release requirement, to be stored in Lower Basin reservoirs.

In the severe drought scenario, Lake Powell contents were drawn down to dead storage by the end of year 18. Active storage in Lake Powell was zero for eight years until the end of year 25. The active contents of Flaming Gorge Reservoir tracked those of Lake Powell; that is, the reservoir contents declined to the dead storage level and remained there for
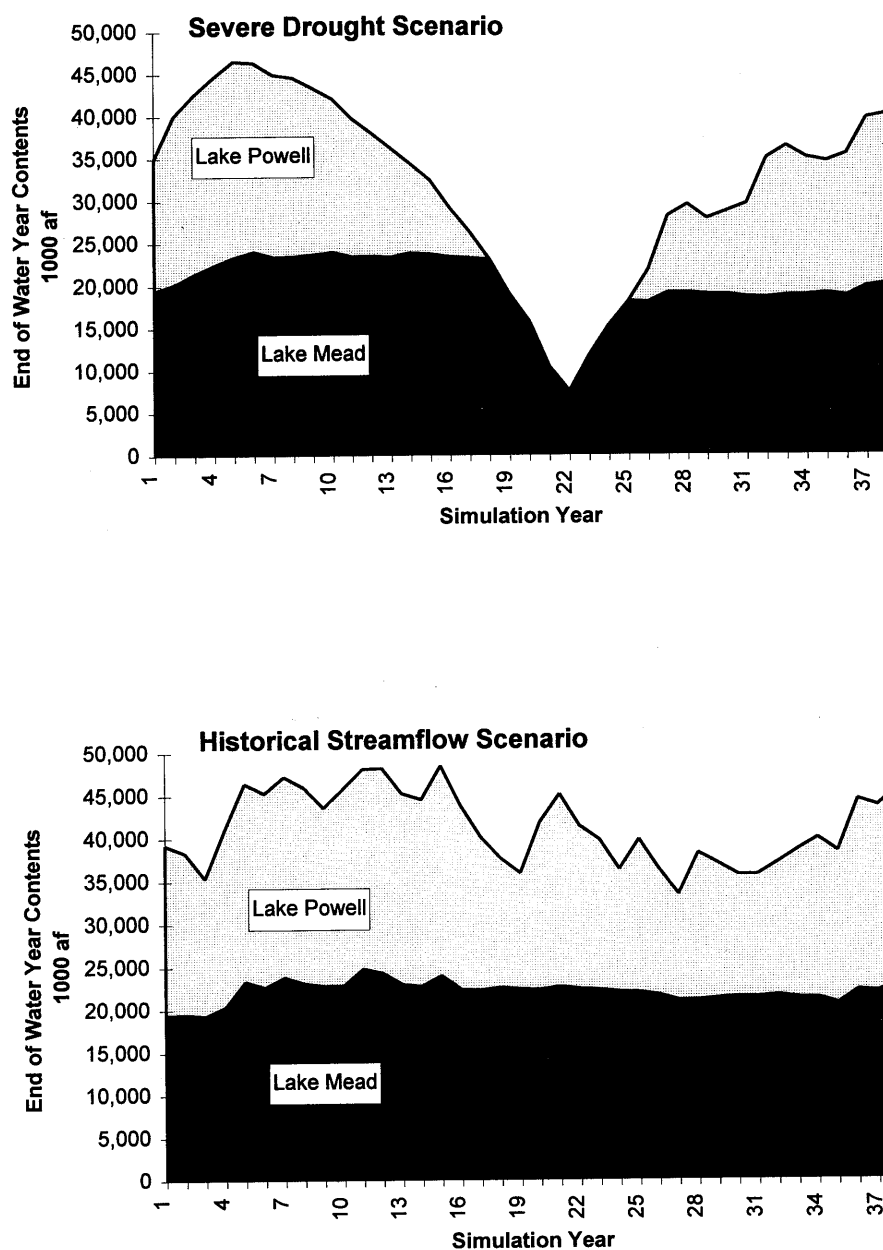
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Figure 3. Simulated Lake Powell and Lake Mead Contents.

several years. In contrast, throughout the historical streamflow scenario, the contents of Lake Powell and Flaming Gorge Reservoir were never drawn down to dead storage. The minimum active storage contents of Lake Powell and Flaming Gorge Reservoir under the historical streamflow scenario were 13.08 and 2.20 maf, respectively.

Lake Mead was not as severely affected as the Upper Basin reservoirs. Under the severe drought scenario the lowest active storage volume observed in Lake Mead was 7.50 maf, in year 22. The relatively high reservoir volumes maintained in Lake Mead occurred because of several reasons:

(a) the Operating Criteria require equalization releases from Lake Powell to Lake Mead as long as the forecasted end-of-water-year contents in Lake Powell exceeded those of Lake Mead (subject to other limitations);

(b) the Operating Criteria also require an annual minimum objective release of 8.23 maf from Lake Powell to Lake Mead; and

(c) the Colorado River Compact requires a 75 maf, 10-year moving total delivery at Lee Ferry.

Salinity

The severe drought would result in increased salinity in the system. The salinity impact would be less severe in the Upper Basin because salinity levels increase from upstream to downstream, so that the greatest effect would be felt by the downstream-most users. Salinity was somewhat mitigated by the shortfalls in Upper Basin, which reduced return flows and thus the salt load, during the worst years of the drought. Salinity below Hoover Dam for the two simulations are summarized in Table 4.

By most measures, the salinity in the river is higher under the severe drought than under the historical streamflows scenario. The one exception is frequency of exceedence of the salinity criterion below Hoover Dam of 723 parts per million (ppm). The criterion was exceeded in 32 of the 38 years in the historical streamflow scenario and was exceeded in 30 of the 38 years in the severe drought scenario. This effect is to some degree a result of the simulation of only active storage rather than total storage in the Colorado River Model; when Lake Powell empties, its salt inventory is eliminated so that, in subsequent months, the reservoir concentration assumes the inflow concentration. In reality, inflows in subsequent months would mix, to some extent, with the highly concentrated water in dead storage, thus extending the period over which salinity levels are elevated.

Hydropower

Colorado River hydropower generation would be considerably lower under a severe drought than under historical streamflows (Table 5). The simulations show that the total annual energy generated in the system would be 84 percent lower in the worst drought year of the severe drought scenario, compared to the minimum generated in the historical streamflow scenario when the contents of Lake Mead fall below the minimum power pool level.

In the severe drought scenario, an abrupt decrease in the generated energy occurred when the level of Lake Powell dropped below the minimum power pool, in year 17 of the drought. Thereafter, the power plant at Glen Canyon Dam (Lake Powell) did not contribute to the total system energy until five years after the drought ended, when the level of Lake Powell rose above the minimum power pool. A second abrupt decrease in the total system energy generation occurred when the level of Lake Mead dropped below the minimum power pool, in year 22 of the severe drought. In that year, the lowest energy generation year in the study period, 73 percent of the total energy generated in the Colorado River system was from the powerplants at Lake Havasu and Lake Mojave.

DISCUSSION

The simulations show that the Colorado River system would be remarkably resilient in the face of an exceptionally extreme, even unrealistic drought of the sort postulated in this study. However, the impacts of the drought would fall disproportionately on the states of the Upper Basin. Our studies indicate that, under the current institutional setting, over half of the Upper Basin consumptive use requests would be unmet in the worst drought year, the same year in

TABLE 4. Colorado River Salinity Below Hoover Dam
(parts per million).

	Average	Maximum	Minimum
Historical Streamflows Scenario	859	1,083	602
Severe Drought Scenario	908	1,530	648

TABLE 5. Colorado River Energy Generation (including 11 power plants)
(annual gigawatt-hours).

	Average	Maximum	Minimum
Historical Streamflows Scenario	9,716	12,673	8,778
Severe Drought Scenario	7,704	10,625	1,439

which Lake Mead held almost 7.5 maf of water in storage. In contrast, the worst Lower Basin shortfall would only be about 3 percent and would occur in Arizona and Nevada. Though California's basic entitlement would be immune to the drought, California's demand for Colorado River water exceeds its normal entitlement. For example, though MWD's Colorado River entitlement is 487,000 af, the Colorado River Aqueduct can deliver 1.2 maf per year and has frequently done so. The frequency of surplus deliveries to MWD would be seriously curtailed under a severe drought. At the same time, deliveries to California agriculture would not be curtailed from their 3.85 maf entitlement.

The disproportionate distribution of impacts in a severe sustained drought suggests the need for institutional coping mechanisms. Several such mechanisms are identified in Henderson and Lord (1995) and evaluated in Sangoyomi and Harding (1995).

LITERATURE CITED

Barr, R. S., F. Glover, and D. Klingman, 1974. An Improved Version of the Out-of-Kilter Method and a Comparative Study of Computer Codes. Mathematical Programming 7:60-86.

Booker, James F., 1995. Hydrologic and Economic Impacts of Drought Under Alternative Policy Responses. Water Resources Bulletin 31(5):889-906.

Brown, Thomas C., B. L. Harding, and W. B. Lord, 1988. Consumptive Use of Incremental Flows in the Colorado River Basin. Water Resources Bulletin 24:801-814.

Brown, Thomas C., B. L. Harding, and E.A. Payton, 1990. Marginal Economic Value of Streamflow: A Case Study for the Colorado River Basin. Water Resources Research 26(12):2845-2859.

Clasen, R. J., 1968. The Numerical Solution of Network Problems Using the Out-of-Kilter Algorithm. Rand Corporation Memorandum RM-5456-PR.

Henderson, James L. and William B. Lord, 1995. A Gaming Evaluation of Colorado River Drought Management Institutional Options. Water Resources Bulletin 31(5):907-924.

Meyers, Charles J., 1966. The Colorado River. Stanford Law Review 19:1-75.

Nathanson, Milton, N., 1978. Updating the Hoover Dam Documents. United States Printing Office, Denver, Colorado.

Sangoyomi, Taiye B. and Benjamin L. Harding, 1995. Mitigating Impacts of a Severe Sustained Drought on Colorado River Water Resources. Water Resources Bulletin 31(5):925-938.

Schuster, Ronald J., 1987. Colorado River Simulation System Documentation, System Overview. U.S. Department of the Interior, Bureau of Reclamation, Denver, Colorado.

Schuster, Ronald J., 1988a. Colorado River Simulation System Documentation, Colorado River Simulation Model User's Manual. U.S. Department of the Interior, Bureau of Reclamation, Denver, Colorado.

Schuster, Ronald J., 1988b. Colorado River Simulation System Documentation, Colorado River Simulation Model Programmer's Manual. U.S. Department of the Interior, Bureau of Reclamation, Denver, Colorado.

Tarboton, David. G., 1995. Hydrologic Scenarios for Severe Sustained Drought in the Southwestern United States. Water Resources Bulletin 31(5):803-813.

Texas Water Development Board, 1972. Economic Optimization and Simulation Techniques for Management of Regional Water Resource Systems; River Basin Simulation Model SIMYLD–II-Program Description. Austin, Texas.