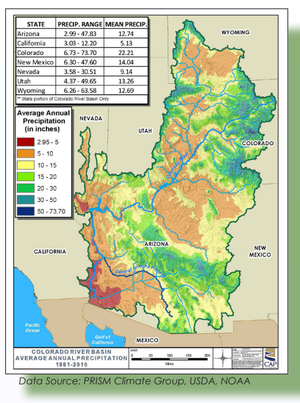
Central Arizona Water Supply Analysis

The Colorado River recently topped the list of America's Most Endangered Rivers for 2013 according to a report by American Rivers, a leading non-profit dedicated to the protection of the nation's rivers. With ever increasing warming trends, drought and population growth in the Southwest, the need to understand the complexities of water supply and demand in central Arizona is a daunting task. At Central Arizona Project (CAP), our management needed more information on the conditions of the Colorado River Basin for better decisions regarding our future water supplies and potential shortages. A series of maps was created to depict various factors affecting the basin (below). In addition, CAP has been implementing several Decision Support System (DSS) modeling approaches and their interconnections to evaluate shortage conditions for CAP under different hydrological and policy scenarios.

Climate Factors



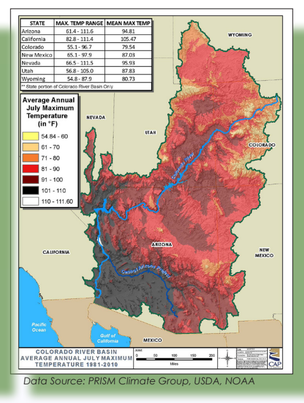
STATE	PRECIP. RANGE	MEAN PRECIP.
Arizona	2.99 - 47.83	12.74
California	3.03 - 12.20	5.13
Colorado	6.73 - 73.70	22.21
New Mexico	6.30 - 47.60	14.04
Nevada	3.58 - 30.51	9.14
Utah	4.37 - 49.65	13.26
Wyoming	6.26 - 63.58	12.69

* State portion of Colorado River Basin Only

Average Annual Precipitation (in inches): 2.95 - 5; 5 - 10; 10 - 15; 15 - 20; 20 - 30; 30 - 50; 50 - 73.70

COLORADO RIVER BASIN AVERAGE ANNUAL PRECIPITATION 1981-2010

Data Source: PRISM Climate Group, USDA, NOAA



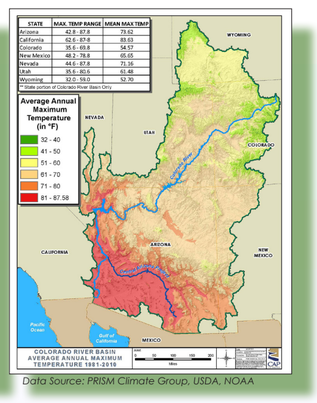
STATE	MAX. TEMP RANGE	MEAN MAX TEMP
Arizona	81.4 - 111.6	94.81
California	82.8 - 111.4	105.47
Colorado	55.1 - 96.7	79.54
New Mexico	65.3 - 97.9	87.03
Nevada	66.5 - 111.5	95.93
Utah	56.8 - 105.0	87.83
Wyoming	54.8 - 87.9	80.73

* State portion of Colorado River Basin Only

Average Annual July Maximum Temperature (in °F): 54 84 - 60; 61 - 70; 71 - 80; 81 - 90; 91 - 100; 101 - 110; 110 - 111.60

COLORADO RIVER BASIN AVERAGE ANNUAL JULY MAXIMUM TEMPERATURE 1981-2010

Data Source: PRISM Climate Group, USDA, NOAA



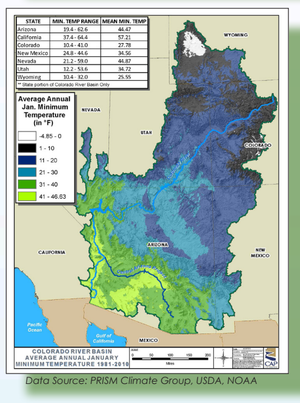
STATE	MAX. TEMP RANGE	MEAN MAX TEMP
Arizona	42.8 - 87.8	75.62
California	62.6 - 87.8	83.63
Colorado	35.6 - 69.8	54.57
New Mexico	48.2 - 78.8	65.65
Nevada	44.6 - 87.8	71.16
Utah	35.6 - 80.6	61.48
Wyoming	32.0 - 59.0	52.70

* State portion of Colorado River Basin Only

Average Annual Maximum Temperature (in °F): 32 - 40; 41 - 50; 51 - 60; 61 - 70; 71 - 80; 81 - 87.58

COLORADO RIVER BASIN AVERAGE ANNUAL MAXIMUM TEMPERATURE 1981-2010

Data Source: PRISM Climate Group, USDA, NOAA



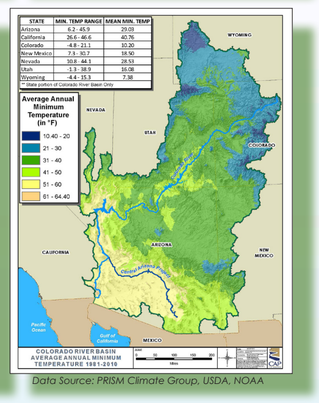
STATE	MIN. TEMP RANGE	MEAN MIN. TEMP
Arizona	39.4 - 62.6	44.47
California	37.4 - 64.4	57.21
Colorado	30.4 - 41.0	27.78
New Mexico	24.8 - 44.6	36.56
Nevada	21.2 - 59.0	46.87
Utah	12.2 - 53.6	34.72
Wyoming	10.4 - 32.0	25.55

* State portion of Colorado River Basin Only

Average Annual Jan. Minimum Temperature (in °F): -4.85 - 0; 1 - 10; 11 - 20; 21 - 30; 31 - 40; 41 - 46.63

COLORADO RIVER BASIN AVERAGE ANNUAL JANUARY MINIMUM TEMPERATURE 1981-2010

Data Source: PRISM Climate Group, USDA, NOAA



STATE	MIN. TEMP RANGE	MEAN MIN. TEMP
Arizona	6.2 - 45.9	29.03
California	36.6 - 46.6	40.76
Colorado	4.8 - 21.1	10.20
New Mexico	7.3 - 31.7	18.50
Nevada	10.8 - 44.1	28.53
Utah	-1.3 - 38.9	16.08
Wyoming	-4.4 - 15.3	7.38

* State portion of Colorado River Basin Only

Average Annual Minimum Temperature (in °F): 10 40 - 20; 21 - 30; 31 - 40; 41 - 50; 51 - 60; 61 - 64.40

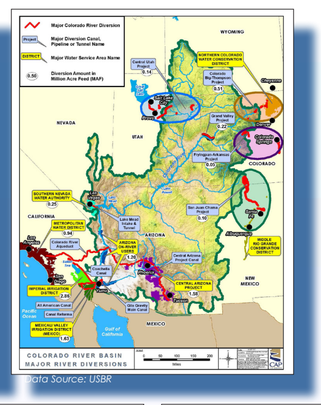
COLORADO RIVER BASIN AVERAGE ANNUAL MINIMUM TEMPERATURE 1981-2010

Data Source: PRISM Climate Group, USDA, NOAA

Water Factors

COLORADO RIVER BASIN AVERAGE ANNUAL NATURAL FLOW

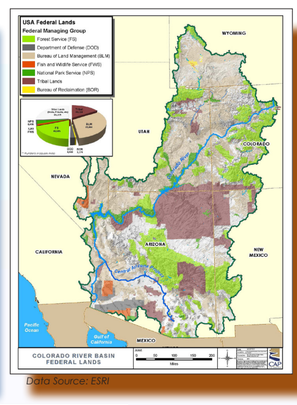
Data Source: USBR 2007



COLORADO RIVER BASIN MAJOR RIVER DIVERSIONS

Data Source: USBR

Land Factors

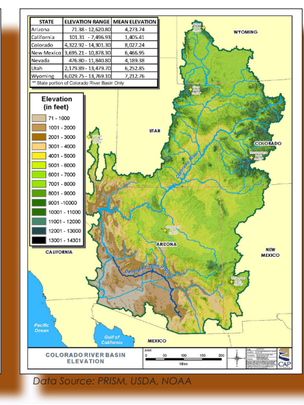


COLORADO RIVER BASIN FEDERAL LANDS

Data Source: ESRI

COLORADO RIVER BASIN LAND COVER

Data Source: USGS Land Cover Institute, MRLC NLCD



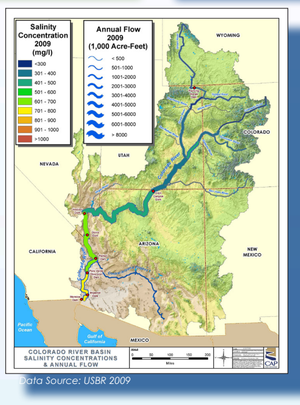
STATE	ELEVATION RANGE	MEAN ELEVATION
Arizona	21.38 - 12,620.59 ft	4,273.74
California	323.31 - 7,496.91 ft	1,405.41
Colorado	4,322.92 - 14,301.35 ft	8,027.24
New Mexico	3,695.71 - 10,878.30 ft	6,466.95
Nevada	426.80 - 11,940.60 ft	4,599.99
Utah	2,179.89 - 13,479.70 ft	6,252.85
Wyoming	14,029.75 - 13,783.91 ft	7,272.76

* State portion of Colorado River Basin Only

Elevation (in feet): 71 - 1000; 1001 - 2000; 2001 - 3000; 3001 - 4000; 4001 - 5000; 5001 - 6000; 6001 - 7000; 7001 - 8000; 8001 - 9000; 9001 - 10000; 10001 - 11000; 11001 - 12000; 12001 - 13000; 13001 - 14001

COLORADO RIVER BASIN ELEVATION

Data Source: PRISM, USDA, NOAA



Salinity Concentration 2009 (mg/l): <500; 501 - 400; 401 - 500; 501 - 600; 601 - 700; 701 - 800; 801 - 900; 901 - 1000; >1000

Annual Flow 2009 (1,000 Acre-Feet): < 500; 501-1000; 1001-2000; 2001-3000; 3001-4000; 4001-5000; 5001-6000; 5001-6000; > 8000

COLORADO RIVER BASIN SALINITY CONCENTRATIONS & ANNUAL FLOW

Data Source: USBR 2009

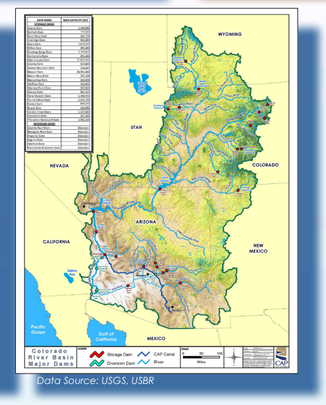
Colorado River Basins; Colorado River Sub-Basins

Total area of Colorado River Basin: approximately 249,000 sq. miles or 159,370,000 Acres

UPPER BASIN; LOWER BASIN

COLORADO RIVER BASINS & SUB-BASINS

Data Source: USGS, ESRI, CONABIO



Colorado River Basin Major Dams

Storage Dam; Diversion Dam; CAP Canal; River

Data Source: USGS, USBR

Legend: National Wildlife Refuge; National Park Boundary

COLORADO RIVER BASIN NATIONAL PARKS & WILDLIFE REFUGES

Data Source: National Park Service

Legend: MSCP Conservation Area; MSCP Planning Area; National Wildlife Refuge

Big Bend Conservation Area; Beal Lake Conservation Area; Planet Ranch (proposed); Palo Verde Ecological Reserve; Cibola Valley Conservation Area; Hart Mine Marsh; Cibola NWR Unit #1; Imperial Ponds Conservation Area; Laguna Division Conservation Area; Yuma East Wetlands (proposed); Hunters Hole

LOWER COLORADO RIVER MULTI-SPECIES CONSERVATION PROGRAM

Data Source: USBR Lower Colorado MSCP

COLORADO RIVER MANAGEMENT

Due to the priorities in the Lower Basin, CAP water deliveries hold a junior priority. CAP deliveries are subject to reductions during shortage events. Under the 2007 interim guidelines, during a shortage condition (where there is not enough water available to supply 7.5 MAF of annual water rights entitlements to the Lower Basin states), Arizona and Nevada would, respectively, share near to 96% and 4% of total water reductions. Given its junior priority, CAP would be the most affected by absorbing approximately 90% of Arizona's total water decreases.

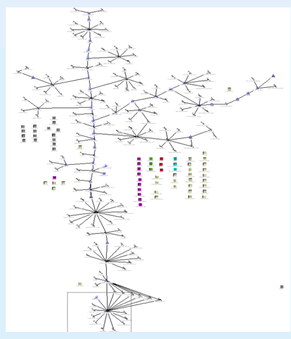
Lake Mead Elev.	Shortage to Arizona	Shortage to CAP
1075 ft	Level 1 – 320,000 af	288,000 af
1050 ft	Level 2 – 400,000 af	360,000 af
1025 ft	Level 3 – 480,000 af	432,000 af

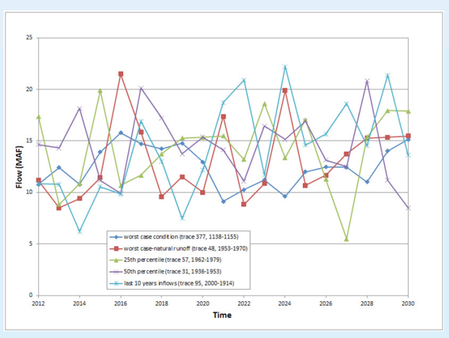
CENTRAL ARIZONA PROJECT SYSTEM MODELS

Given its vulnerability to water shortage conditions, and as part of its planning efforts, CAP is currently implementing several water resource DSS modeling approaches to assist decision making. CAP uses the existing Colorado River Simulation System (CRSS), developed for the US Bureau of Reclamation (USBR) under the RiverWare platform, to evaluate shortage conditions for central Arizona under different scenarios. In addition, CAP is currently developing its own DSS models, using a System Dynamics approach, to investigate the quantitative behavior of components associated with Arizona on-river users, the CAP Service Area, and the CAP physical system. These models are designed to help with decisions regarding Arizona on-river water demand behavior, canal-reservoir operation rules, testing the system reliability for different new water supplies (wheeling), seasonal variations of water demand per segment, optimization of power consumption, and considering groundwater recharge projects for scenarios related with firming and recovery.

THE COLORADO RIVER SIMULATION SYSTEM

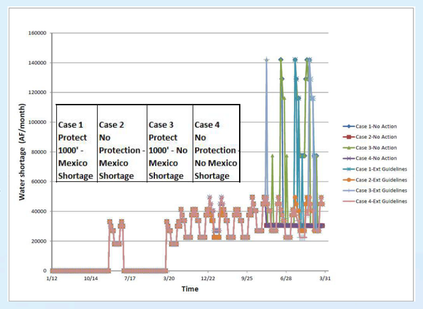
CRSS is the primary modeling tool used in the Bureau of Reclamation's long-term planning studies for the Colorado River Basin. CRSS simulates the operation of the major Colorado River system reservoirs on a monthly time step and provides information regarding the projected future state of the system in terms of output variables. CAP uses CRSS to evaluate river water shortages under different climatic, hydrologic and policy changes.





CRSS Shortage Modeling: Main Findings

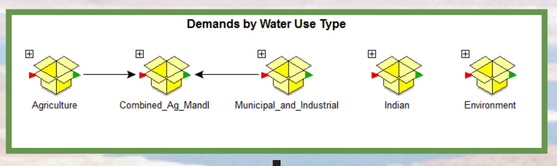
- There is a correlation between magnitude of water shortages and severity of hydrological conditions
- The No-Action alternative increases water shortages on Lower Basin (LB) users as compared to extending the 2007 interim guidelines
- CAP takes the highest burden of lower basin users, from taking on 60% to 90% of shortage under the most extreme cases
- CAP water shortages remain similar for the tested conditions under less extreme hydrological conditions

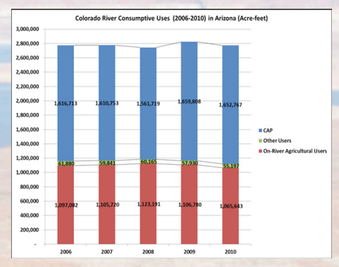


ARIZONA ON-RIVER MODEL

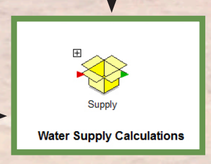
The Arizona on-river model accounts for all of the priority contracts for Colorado River Water in Arizona that take their entitlement directly from the river including the CAP. All individual contracts and their holders are represented, along with the type of use for each contract (e.g. agricultural, municipal/industrial, etc.) under each priority category (Priorities 1 through 4). After Colorado River water has been allocated to on-river priority contract holders, the model determines the volume of water available for CAP to divert from the Colorado River to its service area in central Arizona. Input into the model is water available to Arizona based on Upper Basin hydrology, as modeled through CRSS. The total Colorado River water entitlement for Arizona is 2.8 MAF, and CAP holds a junior priority (Priority 4) in Arizona's Colorado River entitlement, which makes it more vulnerable to water shortages during drought conditions.

The demands by water use type section encompasses calculations for all Arizona on-river water users based on water use type. These calculations, based on the growth rates indicated by the user interface, determine the future projected demand of all Arizona on-river users.

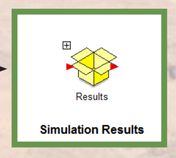




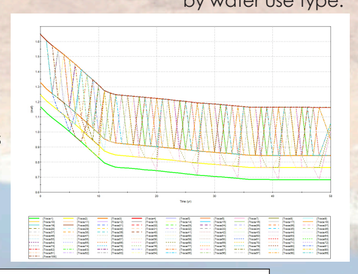
Arizona supply traces are data input that is generated by the CRSS model. This input represents a number of realizations (traces) of Colorado River water supply to Arizona based on a given type of hydrology in the river basin. The generating of the traces through CRSS takes into account hydrologic and climatic conditions in the basin as well as the operating rules of the reservoirs in the system.

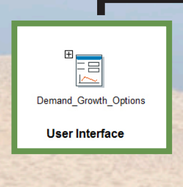


Water supply calculations take into account the demands of all Arizona on-river water users and the Colorado River water supply available to Arizona. These calculations determine what the actual consumptive use of each water user is as a function of how much water is available, their water demands, and the priority of their water entitlement.

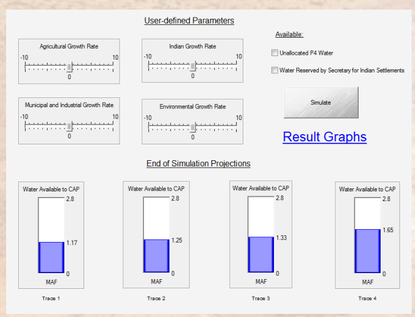


Simulation results are presented in graphical and/or tabular form. Simulation results include the volume of water available for CAP to divert from the Colorado River and the consumptive use of Arizona on-river users, organized by water use type.

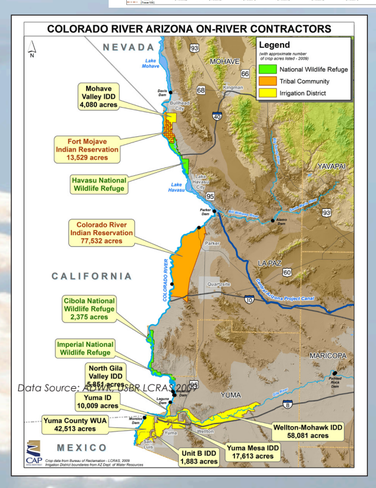




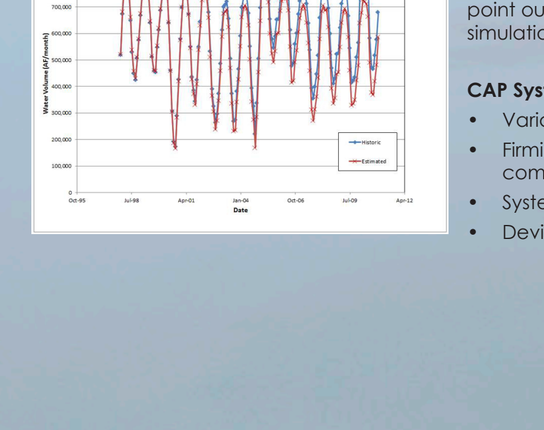
The user interface allows users of the model to directly implement changes in projected water use by applying growth rates to different sectors of water use. It also provides a single-click button for model simulation and a direct link to simulation results.



The Arizona on-river information section of the model provides supplemental information regarding Arizona on-river water users; such as a geographical map of the largest users, identification of users with multiple priority water entitlements, and a list of alternate aliases for a number of users.



CAP SYSTEM MODEL



The CAP System model represents the current CAP water conveyance system, which is composed of the aqueduct, pumping stations, recharge facilities, and the Lake Pleasant reservoir. In the model, the canal is divided into 13 segments, which are sections of the canal between pumping plants. These pumping plants are used to lift diverted Colorado River water and overcome the elevation difference between its origin, Lake Havasu and its terminus, Tucson. The model has a monthly temporal resolution to account for the seasonality component of reservoir operations and variations in water user deliveries.

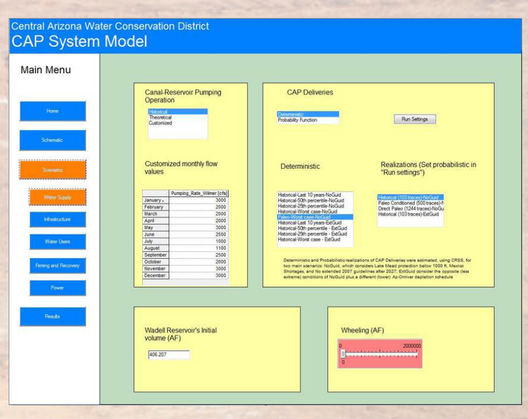
The user interface is composed of four main sections:

Home: documentation/description and main simulation settings for the model

Schematic: Graphical conceptualization of the model and access to elements defining the mathematical representation of the system

Scenarios: Used to test a variety of scenarios for the structural and non-structural components of the system (water supply, infrastructure, power, etc.)

Results: Provides a comprehensive display of simulation results (tables, graphs, exports results to GIS, spreadsheets or databases, etc.)



Lake Pleasant's simulated storage values, especially for the second part of the calibrations period (2001-2010), were consistently lower than the historical values. Preliminary findings point out that adjusting Agua Fria River inflows could improve simulation results as compared with historical values.

CAP System Model - Future modeling activities

- Variations of water user demand per segment
- Firming and Recovery (storage forecasting, and recovery combinations),
- System operation policies
- Devise and define details to facilitate models' connections

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CAP
CENTRAL ARIZONA PROJECT