RECLAMATION

Managing Water in the West

Interim Report No. 1

Colorado River Basin Water Supply and Demand Study

Technical Report D – System Reliability Metrics

U.S. Department of the Interior
Bureau of Reclamation

June 2011

Mission Statements

Protecting America's Great Outdoors and Powering Our Future
The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Interim Report No. 1

Colorado River Basin Water Supply and Demand Study

Technical Report D – System Reliability Metrics

Prepared by:

Colorado River Basin Water Supply and Demand Study Study Team

U. S. Department of the Interior
Bureau of Reclamation

June 2011

Contents

System Reliability Metrics **D-1**

1.0 Introduction **D-1**

2.0 Approach for Metric Development **D-1**
2.1 Step 1 – Resource Categories D-3
2.2 Step 2 – Attribute of Interest D-3
2.3 Step 3 – Location of Interest D-4
2.4 Step 4 – Metric Types (Quantitative or Qualitative) D-5
2.5 Step 5 – Methods for Quantifying Metrics D-5
2.6 Step 6 – Identify Reference Value (if appropriate) D-6
2.6.1 Physical Constraint D-6
2.6.2 Prescribed Condition D-6
2.6.3 Estimated Need D-6
2.6.4 Historical or Simulated Condition D-6
2.7 Step 7 – Documentation D-7
2.8 Examples of Using the Step-wise Approach to Metric Development D-7
2.8.1 Quantitative Type with Direct Measurement D-7
2.8.2 Quantitative Type with Indirect Measurement D-7
2.8.3 Qualitative Type D-8

3.0 Sources of Data and Information Used in Metric Development **D-8**

4.0 Water Deliveries Metrics **D-8**
4.1 Metrics for the Consumptive Uses and Shortages Attribute of Interest D-8
4.2 Metrics for the Water Levels Related to Intake Facilities Attribute of Interest D-9
4.3 Metrics for the Socioeconomic Impacts of Shortages Attribute of Interest D-9

5.0 Electrical Power Resources Metrics **D-9**
5.1 Metrics for the Electrical Power Generated Attribute of Interest D-10
5.2 Metrics for the Economic Value of Electrical Power Generated Attribute of Interest D-11
5.3 Metrics for the Available Generation Capacity Attribute of Interest D-11
5.4 Metrics for the Impact on Power Rates Attribute of Interest D-13
5.5 Metrics for the Water Supply System Pumping Costs Attribute of Interest D-13
5.6 Metrics for the Impact on Basin Funds Attribute of Interest D-14

6.0 Water Quality Resources Metrics **D-14**
6.1 Metrics for the Salinity Attribute of Interest D-14
6.2 Metrics for the Sediment Transport Attribute of Interest D-15
6.3 Metrics for the Temperature Attribute of Interest D-15
6.4 Other Water Quality Attributes of Interest D-16

6.5 Metrics for Socioeconomic Impacts Related to Salinity Attribute of Interest D-16

7.0 Flood Control Metrics D-16
7.1 Metrics for the Flood Control Releases and Reservoir Spills Attribute of Interest D-16
7.2 Metrics for the Critical River Stages Related to Flooding Risk Attribute of Interest D-17

8.0 Recreational Resources Metrics D-17
8.1 Metrics for the Shoreline Public Use Facilities Attribute of Interest D-17
8.2 Metrics for the River and Whitewater Boating Attribute of Interest D-19
8.3 Other Recreational Attributes of Interest D-19
8.4 Metrics for the Socioeconomic Impacts Attribute of Interest D-19

9.0 Ecological Resources Metrics D-19
9.1 Metrics for Threatened and Endangered Species Attribute of Interest D-19
9.2 Metrics for Aquatic and Riparian Habitat Attribute of Interest D-21
9.3 Metrics for Wildlife Refuges and Fish Hatcheries Attribute of Interest D-21

10.0 Status and Next Steps D-22

11.0 References D-24

Disclaimer D-27

Tables

D-1 Resource Categories and Attributes of Interest D-3
D-2 Attribute of Interest: Water Levels Related to Intake Facilities D-9
D-3 Attribute of Interest: Electrical Power Generated D-10
D-4 Attribute of Interest: Available Generation Capacity D-12
D-5 Attribute of Interest: Salinity D-15
D-6 Attribute of Interest: Shoreline Public Use Facility Access D-17
D-7 Attribute of Interest: Flows to Support Threatened and Endangered Species D-20
D-8 Attribute of Interest: Wildlife Refuges and Fish Hatcheries D-21

Figures

D-1 Approach for Metric Development D-2
D-2 Study Area with Locations of Defined Metrics D-23

Appendix

D1 Metrics Sub-Team Members

System Reliability Metrics

1.0 Introduction

The *Plan of Study*, provided in Appendix 1 of the *Status Report*, states that the purpose of the Colorado River Basin Water Supply and Demand Study (Study) is to define current and future imbalances in water supply and demand in the Colorado River Basin (Basin) and the adjacent areas of the seven Colorado River Basin States[1] (Basin States) that receive Colorado River water over the next 50 years, and to develop and analyze adaptation and mitigation strategies to resolve those imbalances. The Study contains four major phases to accomplish this goal: Water Supply Assessment, Water Demand Assessment, System Reliability Analysis, and Development and Evaluation of Opportunities for Balancing Supply and Demand.

System reliability metrics (metrics) are measures that indicate the ability of the Colorado River system to meet the needs of Basin resources[2] under multiple future conditions. Metrics will be used to measure (quantitatively or qualitatively) the potential impacts to Basin resources from current and future water supply and demand imbalances and to measure the effectiveness of options and strategies to remedy those imbalances.

This report describes the approach used to develop metrics and the progress as of January 31, 2011 on their development. Many metrics have been defined, and a description of these metrics is included in this report. Additional metrics are being considered but have not yet been fully defined. Some metrics defined may not prove to be informative or further analysis may identify the need for other metrics. These types of adjustments will be made in the next phase of the Study – System Reliability.

2.0 Approach for Metric Development

Metrics are being developed through a collaborative process involving representatives of numerous organizations, including U.S. Bureau of Reclamation (Reclamation), the Basin States, U.S. Fish and Wildlife Service (FWS), National Park Service (NPS), Western Area Power Administration (Western), Native American tribes and communities, environmental organizations, water delivery contractors, contractors for the purchase of federal power, and others interested in the Colorado River Basin. A Metrics Sub-Team, composed of representatives from some of these organizations, was established to carry out the task of metric development. The Metrics Sub-Team then coordinated with points of contact designated by the other organizations, who provided data, information, and expertise that was critical to the development of the metrics.

The Metrics Sub-Team members and the points of contact from the other organizations are listed in Appendix D1 of this report.

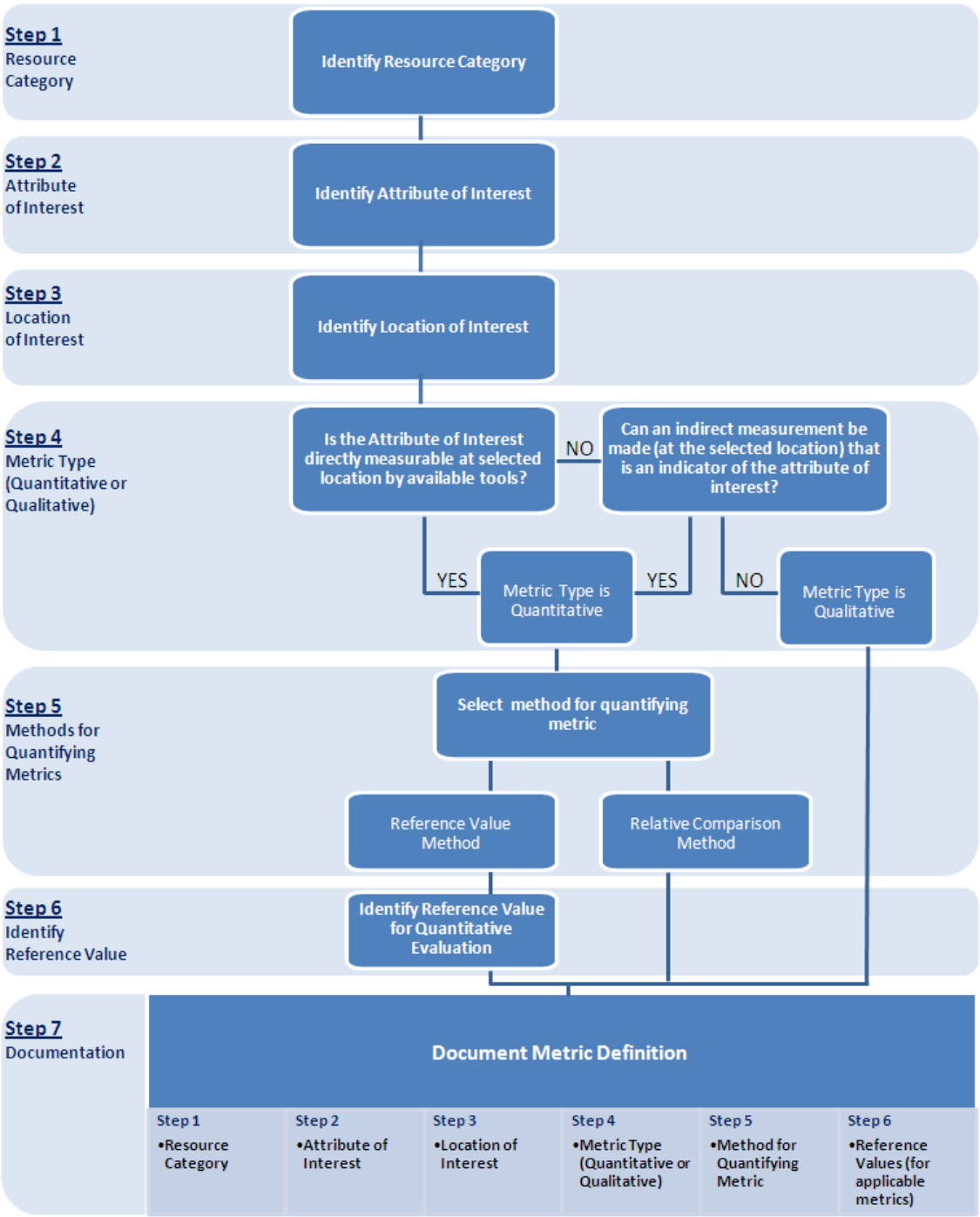
---

[1] Arizona, California, Colorado, New Mexico, Nevada, Utah, and Wyoming

[2] Resources include water allocations and deliveries for municipal, industrial, and agricultural use; hydroelectric power generation; recreation; fish wildlife, and their habitats (including candidate, threatened, and endangered species); water quality including salinity; flow and water dependent ecological systems; and flood control.

The general approach used to develop metrics is presented in Figure D-1. As shown, metric development is a multi-step process, in which each metric presented in this report is fully defined by applying Steps 1 through 7. In the subsequent sub-sections, the individual steps used to develop the metrics are described, and examples are provided to illustrate the development approach.

FIGURE D-1
Approach for Metric Development



2.1 Step 1 – Resource Categories

As stated in the *Plan of Study*:

> "The Study will characterize current and future water supply and demand imbalances in the Basin and assess the risks to Basin resources. Resources include water allocations and deliveries consistent with the apportionments under the Law of the River; hydroelectric power generation; recreation; fish, wildlife, and their habitats (including candidate, threatened, and endangered species); water quality including salinity; flow and water dependent ecological systems; and flood control. "

The following resource categories were developed to reflect these groups of identified resources:

- Water Deliveries
- Electrical Power Resources
- Water Quality Resources
- Flood Control
- Recreational Resources
- Ecological Resources

Socioeconomics is not considered as an independent resource category in the Study. Instead, socioeconomic impacts resulting from water supply and demand imbalances are considered within the principal resource categories, as appropriate.

2.2 Step 2 – Attribute of Interest

An attribute is a specific property or trait that can be associated with a resource category. Several attributes in each resource category that are informative when evaluating system reliability for that category were identified. These attributes are presented in Table D-1 by resource category.

TABLE D-1
Resource Categories and Attributes of Interest

Resource Category	Attribute of Interest
Water Deliveries	• Consumptive Uses[1] and Shortages[2] • Water Levels Related to Intake Facilities • Socioeconomic Impacts Related to Shortages
Electrical Power Resources	• Electrical Power Generated • Economic Value of Electrical Power Generated • Available Generation Capacity • Impact on Power Rates • Water Supply System Pumping Costs • Impacts on the Upper Colorado River Basin Fund, established pursuant to the Colorado River Storage Project Act and the Lower Colorado River Basin Development Fund, established pursuant to the Colorado River Basin Project Act (Basin Funds)

TABLE D-1
Resource Categories and Attributes of Interest

Resource Category	Attribute of Interest
Water Quality	• Salinity • Sediment Transport • Temperature • Other Water Quality Attributes • Socioeconomic Impacts Related to Salinity
Flood Control	• Flood Control Releases and Reservoir Spills • Critical River Stages Related to Flooding Risk
Recreational Resources	• Shoreline Public Use Facilities • River and Whitewater Boating • Other Recreational Attributes • Socioeconomic Impacts Related to Recreation
Ecological Resources	• Threatened and Endangered Species • Aquatic and Riparian Habitats • Wildlife Refuges and Fish Hatcheries

NOTES:
[1] *Consumptive use* is water used, diminishing the available supply.
[2] *Shortage* is unmet demand.
Demand is water needed to meet identified uses.

2.3 Step 3 – Location of Interest

Specific locations where a metric may be evaluated were selected. Locations where metrics may be evaluated include selected points along the Colorado River, its major tributaries, and at selected facilities such as mainstem reservoirs or power generation facilities. Although at this step any location within the Study Area (i.e., the hydrologic boundaries of the Colorado River Basin plus the adjacent areas of the Basin States that receive Colorado River water) may be selected, the spatial and temporal scales of available data (through simulation modeling and other sources) may restrict the locations and/or the analysis that can be performed at a specific location.

The Colorado River Simulation System (CRSS) is the primary modeling tool that will be used in the Study. It 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. Outputs include the amount of water in storage, reservoir elevations, releases from the dams, the amount of water flowing at various points throughout the system, the total dissolved solids content, and diversions to and return flows from the water users throughout the system. Twelve Upper Basin and Lower Basin reservoirs are modeled in CRSS: Fontenelle, Flaming Gorge, Starvation (a representation of several reservoirs within the Central Utah Project in Western Utah), Taylor Park, Blue Mesa, Morrow Point, Crystal, Navajo, Powell, Mead, Mohave, and Havasu. There are approximately 250 diversions and return flows represented in CRSS throughout the Basin. Natural flow is input to the model at 29 locations throughout the Basin (20 in the Upper

Basin upstream of and including the Lees Ferry gaging station in Arizona, and nine below Lees Ferry including the Paria River and other inflow points in the Lower Basin).[3]

2.4 Step 4 – Metric Types (Quantitative or Qualitative)

Metrics will be evaluated in either a quantitative or qualitative fashion. A metric will be evaluated quantitatively if: a) direct evaluation is possible using output from CRSS or results from post-processing of CRSS output data, or b) an indicator of the attribute of interest at the specified location can be developed, based on output from CRSS or post-processing of CRSS output data.

If a particular attribute of interest cannot be represented either directly in CRSS or through the development of an indicator, the potential performance of an attribute under various future scenarios will be discussed qualitatively. Qualitative metrics bypass Steps 5 and 6 and are documented in Step 7.

Qualitative discussions will vary in detail depending on the level of information available. During the System Reliability Analysis phase of the Study, more information will be available, including model results and results from quantitative analyses. Using this information and other information available from published reports and/or articles, the approach for evaluating each qualitative metric and the level to which a qualitative evaluation can be made will be discussed in future interim reports.

Although several metrics will be evaluated in a qualitative manner in the Study, information developed in the Study may be used to guide quantitative assessments in future studies.

2.5 Step 5 – Methods for Quantifying Metrics

If a metric is identified as quantitative, the next step is to select a specific method for quantifying that metric. Two methods for quantifying metrics have been identified:

1. Reference Value Method: In many cases, comparing the attribute of interest at a particular location to a reference value (that may also be specific to the location of interest) informs the assessment of system reliability. The method used to quantify the reference value then defines the method for quantifying the metric. Because the Study is addressing a wide range of Basin resources, no single method for quantifying reference values is applicable to all metrics. Therefore, four different methods for quantifying reference values (and the subsequent metrics) have been defined as of January 31, 2011, as outlined below.

2. Relative Comparison Method: In some cases, an informative reference value may not exist for some attributes of interest. In such cases, the attribute of interest is strictly compared across the range of future water supply and demand scenarios. For example, metrics related to flood control releases or spills to manage reservoir levels may not have an associated reference value. In this case, metrics related to flood control releases or spills will be quantified through a comparative analysis between future scenarios.

[3] Natural flow represents the flow that would have occurred at the location had depletions and reservoir regulation not been present upstream of that location. However, CRSS uses historical inflows based on U.S. Geological Survey streamflow records as estimates of natural flows for the Paria, Little Colorado, Virgin and Bill Williams Rivers. In addition, the Gila River is not included in CRSS. See *Technical Report C – Water Demand Assessment, Appendix C5,* for more detail.

2.6 Step 6 – Identify Reference Value (if appropriate)

Once the reference value method is selected in Step 5, the next step is to select the appropriate reference value. As described below, reference values may be based on physical constraints in the Basin, prescribed conditions, estimated resource needs, or historical or simulated conditions.

2.6.1 Physical Constraint

Some metrics may be quantified based on physical constraints in the river system. For example, the elevation of a facility's water intake represents a physical constraint and provides the reference value that can be used to quantify a metric in the Water Deliveries resource category.

2.6.2 Prescribed Condition

Some metrics may be quantified based on specific values that are prescribed in contracts and agreements between resource management agencies, Environmental Impact Statement (EIS) RODs, Biological Opinions issued by FWS, and other regulatory actions. For example, recommendations of flows for endangered species (as defined in a Biological Opinion) provide reference values that can be used to quantify metrics in the Ecological Resources category.

2.6.3 Estimated Need

Some metrics may be quantified using an estimated need for a water-dependent resource. Estimated needs typically are developed by interested stakeholders or are defined within published reports and articles. For example, the projected demand for municipal, industrial, and agricultural water at a specific location can be used to quantify metrics in the Water Deliveries resource category.

2.6.4 Historical or Simulated Condition

Some metrics may be quantified based on values derived from historical or simulated conditions, particularly when it is important to measure the change in the attribute of interest over time.

Historical values are based on recorded information, where the period of interest may cover a relatively short timeframe (such as the last 10 years) or a longer timeframe (such as the last 100 years or longer). For example, the minimum and median hydroelectric generation over the past 10 years provides reference values that can be used to quantify a metric in the Electrical Power Resources category.

Metrics also may be quantified based on simulated conditions over a specified timeframe, such as the first 5 years of the simulation (e.g., statistics based on first 5 years of a simulation can be used as a reference value for comparison with later years in the simulation). This approach may be used if using a historical condition reference value would be inappropriate given the known level of modeling accuracy associated with simulating the identified attribute. Model accuracy (the ability of a model to simulate the behavior of a physical system) is dependent upon a number of factors, including biases related to how a particular attribute is characterized. By using a simulated condition reference value, the attribute, and the reference value to which the attribute is being compared will have similar model

accuracy. This avoids the mischaracterization of a difference over time as potentially meaningful when it could be related to modeling accuracy.

For example, the simulated maximum monthly flow over the first 5 years of a CRSS simulation is being investigated as a reference value that can be used to quantify metrics in the Ecological Resources category.

2.7 Step 7 – Documentation

Metric definitions developed by applying Steps 1 through 6 (Figure D-1) are documented in tabular fashion similar to what is shown as Step 7 on Figure D-1.

2.8 Examples of Using the Step-wise Approach to Metric Development

In the following discussion, examples are provided of implementing each step in the approach for metric development (Figure D-1). The examples were specifically selected to show the different paths that may be taken when following the steps shown on Figure D-1.

2.8.1 Quantitative Type with Direct Measurement

In the resource category Electrical Power Resources, electrical power generated was identified as an attribute of interest. In Step 3, the locations of interest were identified as the major Colorado River Storage Project power plants[4] in the Upper Basin and Hoover Dam and the Parker-Davis project in the Lower Basin. In Step 4, it was determined that the attribute of interest is directly measurable at the selected locations (CRSS simulates power generation at each of the identified locations); therefore, a quantitative-type metric can be used for this attribute.

In Step 5, the reference value method was selected based on stakeholder input as the method for metric quantification. In Step 6, two reference values for electrical power generated were selected to be the minimum and median power generation over the previous 10 years, which is a Historical Condition method.

2.8.2 Quantitative Type with Indirect Measurement

In the resource category Ecological Resources, aquatic and riparian habitat was identified as an attribute of interest. In Step 3, the locations of interest are under consideration based on stakeholder input. In Step 4, it was determined that this attribute cannot be directly measured (CRSS does not represent specific ecological and biological characteristics related to aquatic and riparian habitat). However, flow conditions at the monthly time step simulated in CRSS could be an indication of the functioning of aquatic and riparian habitat, thus providing an indirect measurement for this attribute.

In Step 5, the reference value method is under consideration in locations where instream flow water rights exist. In Step 6, the reference value for prescribed conditions would therefore be the minimum target flows defined by instream flow water rights (such as those held by the Colorado Water Conservation Board).

[4] Power plants at Lake Powell, Flaming Gorge, Blue Mesa, Morrow Point, and Crystal reservoirs.

2.8.3 Qualitative Type

In the resource category Recreational Resources, socioeconomics related to recreation was identified as an attribute of interest based on stakeholder input. In Step 3, the locations of interest were identified at various locations throughout the Basin, particularly where there was a significant economic benefit from recreation. In Step 4, it was determined that this attribute cannot be directly measured and furthermore, an indirect measurement is not possible (an economic analysis would require additional economic data and modeling that are not currently available). Therefore a qualitative-type metric was selected for this attribute.

3.0 Sources of Data and Information Used in Metric Development

Data sources utilized in the development of the system reliability metrics included recently published reports relevant to Basin water resources and data and information provided by representatives of organizations either participating directly in the Metrics Sub-Team or as designated points of contact. The use of these data and information sources was referenced where appropriate, and a list of these sources is provided in the References for this report.

4.0 Water Deliveries Metrics

The attributes of interest related to water deliveries are:

- Consumptive uses and shortages
- Water levels related to intake facilities
- Socioeconomic impacts related to shortages

4.1 Metrics for the Consumptive Uses and Shortages Attribute of Interest

Consumptive uses and shortages metrics are evaluated at locations throughout the Basin where demand nodes exist within CRSS. All consumptive uses and shortages metrics are quantitative metrics whose reference values are defined by the Estimated Need quantification method. Specifically, the Estimated Need reference values are based on demand projections for the particular water demand scenario being modeled (see *Technical Report C – Water Demand Assessment*).

CRSS model simulates shortages differently for the Upper and Lower Basins. For the Lower Basin, CRSS computes shortages as specified in the 2007 interim guidelines (U.S. Department of the Interior [Interior], 2007) through 2026. Beyond 2026, additional modeling assumptions will be made, and the sensitivity of the modeling results to those assumptions will be analyzed. For the Upper Basin, CRSS does not simulate the complex water rights systems in each state that would be needed to model shortages to individual water right holders. At any particular node (location), the model tracks shortages when the flow is insufficient to meet the local demands. Such a broad simulation greatly underestimates shortages for the major Upper Basin tributaries; however, additional analysis will be conducted within the System Reliability phase to provide a better estimate of these shortages.

4.2 Metrics for the Water Levels Related to Intake Facilities Attribute of Interest

Water is extracted from the Colorado River at numerous locations using instream diversion facilities or reservoir intake structures. Intake structures cannot operate if reservoir water levels are below their respective minimum service elevations. Therefore, the frequency and duration of potential conditions in which water levels drop below minimum intake service elevations is an important measure of system reliability. Critical water intake level data were provided through coordination with the agencies that operate water supply intakes at these locations and are shown in Table D-2. Additional locations related to intake facilities are also being investigated.

TABLE D-2
Attribute of Interest: Water Levels Related to Intake Facilities

Location	Metric Type	Quantification Method	Reference Value
Navajo Indian Irrigation Project Diversion at Navajo Reservoir	Quantitative	Physical Constraint	5,990 feet msl[1]
Southern Nevada Water Authority Intake at Lake Mead			1,000 feet msl[1]

NOTE:
[1] Minimum allowable water levels above mean sea level (msl) where intake/diversion facilities are still operable. Reference values may be current or proposed values based on stakeholder input.

4.3 Metrics for the Socioeconomic Impacts of Shortages Attribute of Interest

To quantitatively evaluate socioeconomic impacts of shortage conditions, an economic model that relates delivery shortages to employment, income, and tax revenue would be required. This model would need to be regional in nature and have the capability to allocate shortages among agricultural and municipal and industrial (M&I) users. Economic models of this type have been built and used in the past (FWS, 1994). However, updating these models to evaluate socioeconomic impacts related to delivery shortages is beyond the scope of the Study. For this reason, socioeconomic impacts related to shortages will be discussed in a qualitative manner.

5.0 Electrical Power Resources Metrics

The attributes of interest related to electrical power resources are:

- Electrical power generated
- Economic value of electrical power generated
- Available generation capacity
- Impact on power rates
- Water supply system pumping costs
- Impacts on Basin funds

5.1 Metrics for the Electrical Power Generated Attribute of Interest

Hydroelectric power generation is directly related to the head on the generating units and the quantity of water flowing through the turbines. The net effective head is the difference between the water level elevation of the reservoir behind a dam and in the tail water below the dam. The net effective head and flow are the two variables that influence hydroelectric power generation of the power plant, measured in megawatts.

Hydroelectric power is generated at numerous locations throughout the Basin. Hydropower plants in the Upper Basin upon which metrics have been developed include the Colorado River Storage Project facilities located at the Lake Powell, Flaming Gorge, Blue Mesa, Morrow Point, and Crystal reservoirs, as well as the power plant at Fontenelle. Hydropower plants in the Lower Basin include the Hoover, Parker and Davis, and Headgate Rock facilities. There are numerous hydropower plants located throughout the Basin. Metrics for these other hydropower facilities will not be developed. However, those who have a particular interest in other hydropower plants may be able to use the results from facilities evaluated in the Study as indicators for facilities not evaluated here.

Western markets power from all Upper Basin power plants as a single power resource, whereas power is marketed separately from each of the hydropower plants in the Lower Basin. Therefore, electrical power generated by Upper Basin facilities is measured by a single aggregate metric. Individual metrics are used to measure electrical power generated at Lower Basin hydropower plants.

Historical hydropower generation conditions at each facility over the previous 10 years were evaluated by Western. Additional reference periods are also under consideration. Hydropower generation in future scenarios will be compared to these historical reference values. Table D-3 provides a summary of the metrics related to electric power generated.

TABLE D-3
Attribute of Interest: Electrical Power Generated

Location	Metric Type	Quantification Method	Reference Value
Upper Basin Power Plants[1]	Quantitative - Direct	Historical Condition[3]	4,948,780 MWh/yr
Hoover Power Plant			3,426,149 MWh/yr
Parker and Davis Power Plants			1,413,475 MWh/yr
Headgate Rock Power Plant	Quantitative Indirect[2]		44,207 MWh/yr

NOTES:
[1] Upper Basin power plants include: Fontenelle, Flaming Gorge, Blue Mesa, Morrow Point, Crystal, and Glen Canyon.
[2] Headgate Rock Dam is not explicitly modeled in CRSS. However, because the reservoir behind Headgate Rock Dam is maintained at a relatively constant elevation, an indirect measurement can be made by relating modeled changes in river flows to electrical power generated at the dam.
[3] Reference values are the minimum power generation that occurred during the 10-year reference period selected by Western of 2000 through 2009. Additional reference periods are also being considered.

MWh/yr = Megawatt-hours per year

5.2 Metrics for the Economic Value of Electrical Power Generated Attribute of Interest

Western markets power and administers power contracts for power produced at Reclamation-owned and -operated hydropower facilities. The economic value of electrical power produced by these facilities is an important measure of system reliability. CRSS calculates the quantity of electrical power generated, and this information can be used in post-processing analyses to directly calculate economic value. Therefore, the relative difference between the economic value of power produced among scenarios can be evaluated quantitatively using the relative comparison quantification method.

5.3 Metrics for the Available Generation Capacity Attribute of Interest

Available generation capacity is a measure of the maximum amount of power that could be produced based on reservoir level and the physical design capacity of the hydropower facility. The available generation capacity affects hydropower ramping operations and overall power system reliability. Ramping is the change in water release from the reservoir that passes through the turbine to meet the electrical load. Both scheduled and unscheduled ramping occurs to meet variations in real-time electrical loads. Western depends on ramping operations to ensure electrical service reliability and an uninterrupted power supply. The higher the available generation capacity, the more flexibility is available in the ramping operations. Therefore, available generation capacity is an important attribute of Electrical Power Resources.

Historical information about available generation capacity (by month) was evaluated. Available generation capacity in future scenarios will be compared to this historical reference. Table D-4 provides a summary of the metrics related to available generation capacity.

TABLE D-4
Attribute of Interest: Available Generation Capacity

Location	Metric Type	Quantitative Method	Reference Value[3] (all values are in MWh/month)											
			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Upper Basin[1]	Quantitative – Direct	Historical Condition[2]	769	672	757	781	874	869	856	783	688	677	670	795
Hoover			856	848	982	889	913	1029	1248	1357	1233	1353	1265	1107
Parker-Davis			275	213	203	198	224	269	270	317	318	319	318	320
Headgate Rock	Quantitative Indirect[2]		13	11	12	12	13	14	16	7	13	13	15	15

NOTES:
[1] Upper Basin power plants include: Fontenelle, Flaming Gorge, Blue Mesa, Morrow Point, Crystal, and Glen Canyon.
[2] Headgate Rock Dam is not explicitly modeled in CRSS. However, because the reservoir behind Headgate Rock Dam is maintained at a relatively constant elevation, an indirect measurement can be made by relating modeled changes in river flows to available generation capacity at the dam.
[3] Reference values are the minimum available generation capacity that occurred during the selected 10-year reference period of 2000 through 2009.

5.4 Metrics for the Impact on Power Rates Attribute of Interest

Western has contracts in place to deliver specified amounts of power to its customers in the Upper Basin. If Upper Basin hydroelectric power facilities cannot produce the contracted power during any given month, Western must buy energy at the market rate to make up these shortfalls. The amount of power that must be purchased at the market rate directly affects the long-term power rates to contract customers. In the Lower Basin, firm contract power delivery agreements are limited to the Parker-Davis Project. Although Western does not have firm contract power delivery agreements for power produced from Hoover Power plant, decreased power plant production would require increased purchases of market rate power by contract customers. Therefore, power generation at all power plants could impact power rates, regardless of whether or not they have firm contract power delivery agreements.

Varying degrees of power generation shortfalls may exist under the various future scenarios to be evaluated. Understanding the impacts of potential generation shortfalls (which may occur with or without the implementation of options and strategies) to power rates is an attribute of interest for Electrical Power Resources. However, power rates paid by contract customers are not directly measurable by CRSS, and updating third-party models to perform this analysis is outside the scope of the Study. Therefore, a qualitative evaluation of the relationship between generation shortfalls and power rates will be included in the Study.

5.5 Metrics for the Water Supply System Pumping Costs Attribute of Interest

Utilities that pump water to their service areas may be negatively affected by increased energy requirements for pumping associated with lower water levels in source water reservoirs. Examples include the Salt River Project (SRP), which extracts cooling water from Lake Powell for the Navajo Generating Station (NGS); the Southern Nevada Water Authority (SNWA), which diverts water from Lake Mead; the Metropolitan Water District of Southern California (MWD), which diverts water from Lake Havasu through the Colorado River Aqueduct; and the Central Arizona Water Conservation District, which also diverts water from Lake Havasu to supply the Central Arizona Project (CAP) delivery area. Current operating practices maintain relatively constant lake levels in Lake Havasu regardless of hydrologic conditions. Pumping costs for the Colorado River Aqueduct and CAP, therefore, do not fluctuate significantly with hydrologic conditions. For this reason, quantitative metrics at this location are not deemed necessary.

Alternatively, wide fluctuations in water levels in Lake Mead and Lake Powell could impact pumping costs for water providers that pump from these reservoirs. For example, SNWA uses variable-speed pumping equipment that has the ability to adjust power usage with varying lake levels. Therefore, quantitative metrics have been developed for SNWA pumping costs. Conversely, the SRP uses constant speed pumping equipment for the NGS, which is lower-cost equipment, but does not have the ability to adjust power usage with lake levels. Therefore, electrical costs for pumping water to the NGS will not fluctuate significantly with hydrologic conditions. For this reason, quantitative metrics for the NGS are not deemed necessary.

Additional pumping stations currently exist along the Colorado River, and more pumping facilities are anticipated in the future. Therefore, additional metrics related to pumping costs are also under consideration.

5.6 Metrics for the Impact on Basin Funds Attribute of Interest

A portion of the revenue from the sale of power generated at hydropower facilities is used to finance Basin funds, which include the Upper Colorado River Basin Fund, Lower Colorado River Basin Development Fund, Colorado River Dam Fund, and the Parker-Davis Account. These funds provide revenue for a variety of uses, including the operation and maintenance of hydroelectric facilities and associated dams and/or repayment of specific Basin projects or programs. Western is responsible for marketing and collecting payment for power and transfer of revenues to Basin funds. A change in the amount of available capacity or energy generation could potentially affect the revenue derived from the sale of power and the contributions to the Basin funds.

The impact to Basin funds depends on numerous factors, including amount of power sold, economic value of that power, and revenue allocation agreements. CRSS does not directly calculate any of these quantities. However, it does calculate hydropower generation, and varying degrees of hydropower generation shortfalls may exist under the various future scenarios to be evaluated. Therefore, qualitative metrics will be used to relate power generation shortfalls to increased risk of funding shortfalls.

6.0 Water Quality Resources Metrics

The attributes of interest related to water quality resources are:

- Salinity
- Sediment transport
- Temperature
- Other water quality attributes
- Socioeconomic impacts related to salinity

6.1 Metrics for the Salinity Attribute of Interest

The U.S. Environmental Protection Agency (USEPA) suggested the development of water quality criteria for salinity in the Basin following passage of the Federal Water Pollution Control Act (Clean Water Act) of 1972. In response, the Basin States formed the Colorado River Basin Salinity Control Forum (Forum) to develop salinity criteria and an implementation plan to provide compliance while allowing the Basin States to continue to develop their Compact-allocated water. The Forum recommends, the States adopt, and the EPA approves the flow-weighted average annual salinity criteria for three locations on the lower Colorado River (Table D-5). The criteria, first established in 1975, are reviewed every 3 years; the latest review was completed in 2008.

Minute No. 242 of the International Boundary and Water Commission limits the differential in annual average salinity between Imperial Dam and the Northerly International Boundary to 115 parts per million ±30 parts per million. Real-time water operations ensure that the salinity differential is met each year.

CRSS performs salinity calculations for select locations in the Lower Basin, including below Hoover Dam, below Parker Dam, and at Imperial Dam. Therefore, quantitative metrics for salinity have been identified at these locations based on the Forum-developed salinity criteria. CRSS does not include the complex surface water/groundwater interactions in the Yuma, Arizona region from Imperial Dam to the Northerly International Boundary.

Table D-5 provides a summary of the metrics related to salinity.

TABLE D-5
Attribute of Interest: Salinity

Location	Metric Type	Quantification Method	Reference Value
Below Hoover Dam	Quantitative	Prescribed	723 mg/L[1]
Below Parker Dam			747 mg/L[1]
At Imperial Dam			879 mg/L[1]

NOTES:
[1] Salinity measured as flow-weighted average annual total dissolved solids at designated locations on the Colorado River developed by the Forum.

mg/L= milligram(s) per liter

6.2 Metrics for the Sediment Transport Attribute of Interest

After dams were constructed in the Basin, the reservoirs behind these dams retained the vast majority of the inflowing sediment. Following dam closure, large sediment deltas formed near the inflow areas. When the reservoirs are drawn down during droughts, new channels are cut through the sediment deltas. The suspended sediments have a significant oxygen demand and also temporarily release nutrients that can result in greater algal growth.

Riverine sediment transport, therefore, can have recreation and biological resource impacts. Sediment transport in the Basin is not modeled by CRSS. Although sediment transport models exist for some locations, there is no Basin-wide sediment transport model. Potential impacts of sediment transport on the health of aquatic species will be qualitatively addressed with metrics in the Ecological Resources category. Also, the relation between beach formation in reservoirs and within river reaches, and the recreational experience will be addressed qualitatively in the Recreational Resources resource category.

6.3 Metrics for the Temperature Attribute of Interest

Impounding water in reservoirs affects the water temperature of dam releases due to thermal stratification. During the summer, the surface layers of the reservoirs are typically warm as the result of inflows, ambient air temperature, and solar radiation. Conversely, lower reservoir layers remain cooler year-round. For these reasons, water temperatures downstream of reservoirs are influenced by reservoir water level, release facility location, and release volumes.

Water temperature can affect the health of flow- and water-dependent species in the Basin. Water temperature is not modeled by CRSS and therefore will not be quantitatively evaluated in the Study. The importance of water temperature to aquatic species will be addressed qualitatively under the Ecological Resources category.

6.4 Other Water Quality Attributes of Interest

Numerous other water quality attributes are of interest to various stakeholders. Water quality attributes such as selenium, dissolved oxygen, nutrients, algae, metals, perchlorate, and emerging contaminants will be qualitatively addressed in the Study.

6.5 Metrics for Socioeconomic Impacts Related to Salinity Attribute of Interest

Economic impacts of elevated salinity levels in the Colorado River and its tributaries are not calculated by CRSS. Reclamation and the Forum use the Lower Colorado Salinity Damage Model to estimate economic damages that result from elevated salinity levels in the Basin. Economic damages estimated by this model include changes to crop yields related to agricultural water use and impacts due to M&I water use, such as reduced useful life of water-dependent appliances, increased use of water-softening chemicals, and increased purchase of bottled water. Using output from this economic model, economic impacts related to elevated salinity levels may be evaluated quantitatively for some future scenarios.

In addition, USEPA has set voluntarily guidelines for salinity levels in drinking water supplies with a target of less than 500 mg/L, measured as total dissolved solids. Some water providers, notably MWD, blend Colorado River water with other water supplies that have lower salinity in an attempt to meet these guidelines. When salinity levels are elevated in the Colorado River, the ability of M&I water suppliers to meet their target blended salinity is diminished. Qualitative discussions of this item may be provided to complement the quantitative economic damages.

7.0 Flood Control Metrics

The attributes of interest related to flood control are:

- Flood control releases and reservoir spills
- Critical river stages related to flooding risk

7.1 Metrics for the Flood Control Releases and Reservoir Spills Attribute of Interest

The term “flood control releases” is unique to the operation of Hoover Dam because Lake Mead’s annual release is governed by strict flood control regulations. The current flood control regulations were implemented under the Field Working Agreement (between the U.S. Army Corps of Engineers and Reclamation in 1984, as prescribed by the *Water Control Manual* of December 1982). Under this agreement, criteria are set forth to meet system space requirements from August through December and to determine reservoir releases from January through July. During all months of the year, the top 1.5 million acre feet of space (the space above elevation 1,219.6 feet msl) is reserved exclusively for flood control purposes. Lake Mead is considered to be under flood control operations when releases in excess of those necessary to meet water use demands are required to make this flood control space available.

Reclamation also makes “spill avoidance” decisions at other reservoirs it manages and operates. The primary objective of spill avoidance is to minimize the amount of water that does not pass through hydropower facilities. Therefore, Reclamation typically defines a spill

as any amount of water that does not pass through the hydropower facilities, including water that is diverted around the dam through bypass piping as well as water that physically passes over the dam spillway.

CRSS can be used to quantify the frequency and magnitude of both flood control releases at Lake Mead and reservoir spills. These metrics will be quantified at Fontenelle, Flaming Gorge, Blue Mesa, Navajo, Lake Powell, and Lake Mead using the relative comparison quantification method.

7.2 Metrics for the Critical River Stages Related to Flooding Risk Attribute of Interest

CRSS does not directly calculate water levels (stages) in river reaches. In select locations, empirical relationships between river flow and river stage can be used to assess the potential for flooding. Specifically, empirical relationships between flow and flood risk exist downstream of Lake Mead, Navajo Dam, and the Aspinall Unit. Therefore, additional analysis of CRSS output data will be performed to estimate flooding potential, and quantitative metrics using the relative comparison method will be used at these locations. At other critical river reaches, river operations, and flood control will be evaluated qualitatively.

8.0 Recreational Resources Metrics

The attributes of interest related to recreational resources are:

- Shoreline public use facilities
- River and whitewater boating
- Other recreation attributes
- Socioeconomic impacts related to recreation

8.1 Metrics for the Shoreline Public Use Facilities Attribute of Interest

Access to boat launch ramps and marinas is directly related to reservoir water levels. CRSS calculates water levels for all major Basin reservoirs, so access to shoreline facilities can be evaluated directly with CRSS output. Low reservoir levels can also limit reservoir boating navigation and affect ferry service. Table D-6 provides a summary of the metrics for shoreline access.

TABLE D-6
Attribute of Interest: Shoreline Public Use Facility Access

Location	Metric Type	Quantitative Method	Reference Value[1] (ft above msl)
Flaming Gorge	Quantitative	Physical Constraint	
Cedar Springs Marina and Firehole Boat Ramps, Sunny Cove Swim Beach			6,018
Antelope Flat, Anvil Draw, Buckboard, Sheep Creek, Squaw Hollow Boat Ramps			6,015
Mustang Ridge and Upper Marsh Creek Boat Ramps			6,011

TABLE D-6
Attribute of Interest: Shoreline Public Use Facility Access

Location	Metric Type	Quantitative Method	Reference Value[1] (ft above msl)
Lucerne Valley Marina, Kingfisher Island Boat Ramp	Quantitative	Physical Constraint	6,010
Lucerne Valley Boat Ramp			5,994
Blue Mesa			
Elk Creek Marina			TBD
Elk Creek Boat Ramp			TBD
Lake Fork Marina			TBD
Lake Fork Boat Ramp			TBD
Navajo			
Sims Mesa Boat Ramp			6,000
Pine Boat Ramp			5,997
Arboles Boat Ramp			5,978
Lake Powell			
Rainbow Bridge			3,650
Hite Marina, Hite Public Boat Ramp, Castle Rock Cut			3,620
Antelope Point Public Boat Ramp			3,588
Bull Frog Boat Ramp			3,580
Wahweap, Stateline, Bull Frog Low Water Alternative, Halls Crossing Ramps			3,560
Wahweap, Antelope Point, Bull Frog, Halls Crossing Marinas			3,555
Lake Mead			
Pearce Bay Boat Ramp and Ferry			1,175
Grand Wash Access			1,170
Las Vegas Bay and Government Wash Boat Ramps			1,150
Overton Beach Marina and South Cove Boat Ramp			1,125
Lake Mead Marina			1,112
Lake Mead, Hemenway, Temple Bar Boat Ramps			1,080
Echo Bay Boat Ramp			1,050

NOTE:
[1] Minimum reservoir levels required for use of designated shoreline public use facilities. Below these levels, facilities would have to be extended, closed, or relocated.

TBD = to be determined

8.2 Metrics for the River and Whitewater Boating Attribute of Interest

The river and whitewater boating experience varies with flow conditions. Specific recommended flow conditions do not exist for river boating in most Basin river reaches. Qualitative evaluations will be provided for this recreational attribute.

8.3 Other Recreational Attributes of Interest

As mentioned in the discussion of water quality resources, sediment transport affects the recreational experience along Basin rivers and in Basin reservoirs. Significant additional analyses (beyond CRSS) are required to model sediment transport. Therefore, in lieu of detailed quantitative analyses, qualitative evaluations relating sediment transport to river flows will be provided as part of the Study.

8.4 Metrics for the Socioeconomic Impacts Attribute of Interest

A reduction in the number of recreational visitors as a result of limited shoreline access could adversely affect local socioeconomics. Rough estimates that relate reservoir levels or flow conditions to socioeconomic impacts exist for some areas in the Basin. Significant additional analyses (beyond CRSS) are required to model the socioeconomic impacts related to reduced recreational use. For this reason, socioeconomic impacts related to reduced recreational use of Basin water resources will be evaluated qualitatively.

9.0 Ecological Resources Metrics

Colorado River ecosystems support a wide array of native species, each with diverse needs. To assess the response of these ecosystems to changed conditions under future scenarios, extensive data and models that examine the complex interactions of the physical environment and specific species' needs are required. This detailed level of assessment is beyond the scope of the Study; however, information developed in the Study may be used to guide these types of assessments in future studies.

Ecological resources specified in the *Plan of Study* include fish, wildlife, and their habitats; candidate, threatened and endangered species; and flow- and water-dependent ecological systems. The attributes of interest related to ecological resources are:

- Threatened and endangered species
- Aquatic and riparian habitats
- Wildlife refuges and fish hatcheries

9.1 Metrics for Threatened and Endangered Species Attribute of Interest

The Upper Colorado River Endangered Fish Recovery Program and San Juan River Basin Recovery Implementation Program (Recovery Programs) are designed to help recover several fish species listed as endangered under the Federal Endangered Species Act (the Colorado pikeminnow, the razorback sucker, the bonytail, and the humpback chub), while allowing water development to continue in the Upper Colorado and San Juan River Basins. Flow recommendations are defined as part of the Recovery Programs; therefore, flows are used as indicators for metrics for these fish species, and the Recovery Program recommendations provide the reference values.

Table D-7 summarizes the metrics related to flows to support threatened and endangered fish, including the location, flow target(s), and reference document from which these flows were taken.

TABLE D-7
Attribute of Interest: Flows to Support Threatened and Endangered Species

Location	Metric Type	Quantitative Method	Reference Value	Reference
Colorado River near Cameo, CO	Quantitative	Prescribed[1]	Spring peak flows ranging from 12,900-23,500 cfs depending on hydrologic year type	Recovery Program (Osmundson et al., 1995)
Gunnison River near Grand Junction, CO			Spring peak flows ranging from 900-8,700 cfs and summer through winter base flows ranging from 750-2,500 cfs depending on hydrologic year type	Recovery Program (McAda, 2003)
Yampa River near Maybell, CO			Spring peak flows ranging from 4,100-7,000 cfs and summer through winter base flows ranging from 100-335 cfs depending on hydrologic year type	Recovery Program (Modde et al., 1999)
Green River near Greendale, UT	Quantitative	Prescribed[1]	Summer through winter base flows ranging from 800-1,800 cfs depending on hydrologic year type	Flaming Gorge Operations Final EIS (Reclamation, 2005)
Green River at Jensen, UT			Spring peak flows ranging from 8,300-18,600 cfs and summer through winter base flows ranging from 700-2,300 cfs depending on hydrologic year type	Flaming Gorge Operations Final EIS (Reclamation, 2005)
Duschesne River near Randlett, UT			Spring peak flows ranging from 2,500-3,000 cfs and summer through winter base flows ranging from 50-115 cfs depending on hydrologic year type	Recovery Program (Modde et al., 2003)
San Juan River near Bluff, UT[2]			TBD	Navajo Operations Final EIS (Reclamation, 2006)

NOTES:

[1] These flow targets are one component of the Upper Colorado River Endangered Fish Recovery Agreement between Interior and the states of Colorado, Utah, and Wyoming; and several Programmatic Biological Opinions that are based on that agreement and the underlying program. These flow targets may change in the future as a result of new information or changes in this Program or the underlying Programmatic Biological Opinions.

[2] CRSS does not presently have the appropriate resolution to measure flow recommendations at the precise locations specified in the Navajo ROD. Methods have been developed, in collaboration with Navajo Reservoir operators, to provide a quantitative approximation of the Navajo ROD flow recommendations that assume the recommendations are measured at the San Juan River near Bluff, UT.

cfs= cubic feet per second

In the Lower Basin, the Lower Colorado River Multi-Species Conservation Program (LCR MSCP) provides Endangered Species Act compliance for specific federal ongoing and future flow and non-flow related actions in the Lower Basin for 50 years, as well as the conservation plan for a non-federal section 10(a)(1)(B) permit over the same period of time. The LCR MSCP-covered activities include changes in points of diversion that could result in reduced flows in amounts up to 845 thousand acre-ft per year (kafy) in the reach below Hoover Dam to Davis Dam, up to 860 kafy in the reach below Davis Dam to Parker Dam, and up to 1,574 kafy in the reach below Parker Dam to Imperial Dam. Reductions in flow may occur from actions such as water transfers, conservation activities, and shortages to Lower Basin water users (Reclamation, 2004). The flow reduction values at these locations provide the reference values for metrics associated with threatened and endangered species in the Lower Basin.

9.2 Metrics for Aquatic and Riparian Habitat Attribute of Interest

At some locations of interest, specific habitat needs have not been expressed in terms of flow recommendations. However, there is interest in examining how aquatic and riparian habitat for species not currently threatened or endangered may change with time under varying future scenarios. Therefore, the following indicators are being considered:

- Minimum and maximum flows
- Distribution of hydrologic year types
- Frequency and duration of high and low flows

Reference value methods are being considered for these indicators. Specifically, prescribed conditions and historical or simulated condition reference values are being considered. For example, the prescribed condition reference value method could be used when minimum flows are defined by instream water rights, such as those held by the Colorado Water Conservation Board.

9.3 Metrics for Wildlife Refuges and Fish Hatcheries Attribute of Interest

Table D-8 provides a summary of wildlife refuge and fish hatcheries in the Basin that have water rights. Reference values for these metrics are under development.

TABLE D-8
Attribute of Interest: Wildlife Refuges and Fish Hatcheries

Location	Metric Type	Quantification Method	Reference Value
Colorado			
Browns Park National Wildlife Refuge	Quantitative	Prescribed: Colorado Water Right	TBD
Wyoming			
Seedskadee National Wildlife Refuge	Quantitative	Prescribed: Wyoming Water Right	TBD

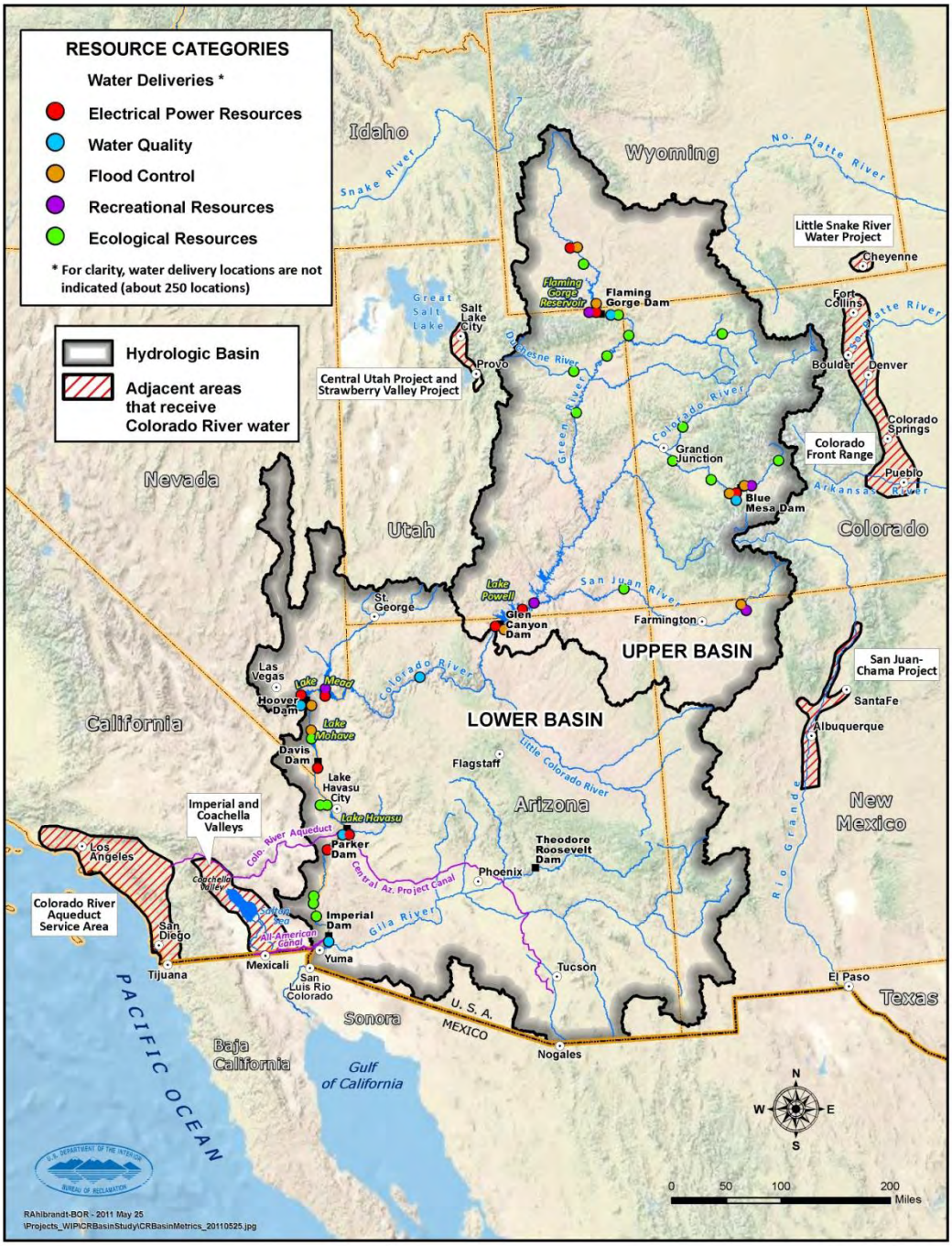
TABLE D-8
Attribute of Interest: Wildlife Refuges and Fish Hatcheries

Location	Metric Type	Quantification Method	Reference Value
Utah			
Ouray National Wildlife Refuge	Quantitative	Prescribed: Utah Water Right	TBD
Arizona			
Willow Beach Fish Hatchery	Quantitative	Prescribed: Entitlement	TBD
Havasu National Wildlife Refuge			TBD
Cibola National Wildlife Refuge			TBD
Imperial National Wildlife Refuge			TBD

10.0 Status and Next Steps

Many metrics have been defined, and descriptions of these metrics have been provided in this report. The map shown in Figure D-2 displays the Study Area and denotes the locations of the metrics that have been defined as of January 31, 2011. The locations of the Water Deliveries metrics are not denoted because there are more than 200 locations throughout the Study Area.

FIGURE D-2
Study Area with Locations of Defined Metrics



Work is ongoing to identify additional metrics and further define metrics that have been identified. These metrics will be included in subsequent interim reports. It is also possible that some defined metrics may not prove to be informative, or further analysis may identify the need for other metrics. These types of adjustments will be made in the next phase of the Study (System Reliability) and documented in future interim reports.

11.0 References

Clean Water Coalition (2006). Systems Conveyance and Operations Program Environmental Impact Statement. Final Draft. Clark County, Nevada. Prepared by Bureau of Reclamation , Boulder City, Nevada, and National Park Service, Boulder City, Nevada.

Interior (2007). U.S. Department of the Interior. Record of Decision – Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead. December, 2007. Washington, D.C.

McAda, C (2003). Flow Recommendations to Benefit Endangered Fishes in the Colorado and Gunnison Rivers. Prepared by U.S. Fish and Wildlife Service. Grand Junction, Colorado.

Modde, T. and C. Keleher (2003). Flow Recommendations for the Duchesne River with a Synopsis for Information Regarding Endangered Fish. Prepared by U.S. Fish and Wildlife Service. Denver, Colorado and Central Utah Water Conservancy District.

Modde, T. et al (1999). Flow Recommendations for Endangered Fishes in the Yampa River Dry Conditions, Non-Dry Conditions. Prepared by U.S. Fish and Wildlife Service. Denver, Colorado.

Muth R.T. et al (2000). Flow and Temperature Recommendations for Endangered Fishes in the Green River Downstream of Flaming Gorge Dam. Prepared by Upper Colorado River Endangered Fish Recovery Program. Denver, Colorado.

Osmundson, Nelson, et al (1995). Relationship between Flow and Rare Fish Habitat in 15-mile Reach. Prepared by U.S. Fish and Wildlife Service and Bureau of Reclamation, Denver, Colorado.

Reclamation (2004). Bureau of Reclamation, U.S Fish and Wildlife Service, and The Metropolitan Water District of Southern California. Lower Colorado River Multi-Species Conservation Program. Volume I: Programmatic Environmental Impact Statement/Environmental Impact Report. Final. December 17, 2004. Sacramento, California.

Reclamation (2005). Bureau of Reclamation. Operation of Flaming Gorge Dam. Environmental Impact Statement. Final. September, 2005. Salt Lake City, Utah.

Reclamation (2006). Bureau of Reclamation. Navajo Reservoir Operations. Environmental Impact Statement. Final. April, 2006. Grand Junction - Durango, Colorado.

Reclamation (2007). Bureau of Reclamation. Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead. Environmental Impact Statement. Final. November 2, 2007. Boulder City, Nevada.

Reclamation (2008). Bureau of Reclamation. Environmental Assessment for Glen Canyon Dam Long-Term Experimental Plan. Final. February, 2008. Salt Lake City, Utah.

Reclamation (2009). Bureau of Reclamation. Draft Environmental Impact Statement Aspinall Unit Operations. Draft January 2009. Grand Junction, Colorado.

Reclamation and USACE (1984). Field Working Agreement between Reclamation and USACE for Flood Control Operation of Hoover Dam and Lake Mead, Colorado River, Nevada and Arizona, as prescribed by the Water Control Manual of December 1982.

U.S. Fish and Wildlife Service (1994). Recovery program: Endangered and threatened species. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Washington, D.C.

Disclaimer

The Colorado River Basin Water Supply and Demand Study (Study) is funded jointly by the Bureau of Reclamation (Reclamation) and the seven Colorado River Basin States (Basin States). The purpose of the Study is to analyze water supply and demand imbalances throughout the Colorado River Basin and those adjacent areas of the Basin States that receive Colorado River water through 2060; and develop, assess and evaluate options and strategies to address the current and projected imbalances.

Reclamation and the Basin States intend that this Study will promote and facilitate cooperation and communication throughout the Basin regarding the reliability of the system to continue to meet Basin needs and the strategies that may be considered to ensure that reliability. Reclamation and the Basin States recognize the Study will have to be constrained by funding, timing and technological and other limitations, which may present specific policy questions and issues, particularly related to modeling and interpretation of the provisions of the Law of the River during the course of the Study. In such cases, Reclamation and the Basin States will develop and incorporate assumptions to further complete the Study. Where possible, a range of assumptions will typically be used to identify the sensitivity of the results to those assumptions.

Nothing in the Study, however, is intended for use against any Basin State, the Federal government or the Upper Colorado River Commission in administrative, judicial or other proceedings to evidence legal interpretations of the law of the river. As such, assumptions contained in the Study or any reports generated during the Study do not, and shall not, represent a legal position or interpretation by the Basin States, Federal government or Upper Colorado River Commission as it relates to the law of the river. Furthermore, nothing in this Study is intended to, nor shall this Study be construed so as to, interpret, diminish or modify the rights of any Basin State, the Federal government, or the Upper Colorado River Commission under federal or state law or administrative rule, regulation or guideline, including without limitation the Colorado River Compact, (45 Stat. 1057), the Upper Colorado River Basin Compact (63 Stat. 31), the Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, Treaty Between the United States of America and Mexico (Treaty Series 994, 59 Stat. 1219), the United States/Mexico agreement in Minute No. 242 of August 30, 1973, (Treaty Series 7708; 24 UST 1968) or Minute No. 314 of November 26, 2008, or Minute No. 318 of December 17, 2010, the Consolidated Decree entered by the Supreme Court of the United States in Arizona v. California (547 U.S 150 (2006)), the Boulder Canyon Project Act (45 Stat. 1057), the Boulder Canyon Project Adjustment Act (54 Stat. 774; 43 U.S.C. 618a), the Colorado River Storage Project Act of 1956 (70 Stat. 105; 43 U.S.C. 620), the Colorado River Basin Project Act of 1968 (82 Stat. 885; 43 U.S.C. 1501), the Colorado River Basin Salinity Control Act (88 Stat. 266; 43 U.S.C. 1951), the Hoover Power Plant Act of 1984 (98 Stat. 1333), the Colorado River Floodway Protection Act (100 Stat. 1129; 43 U.S.C. 1600), or the Grand Canyon Protection Act of 1992 (Title XVIII of Public Law 102-575, 106 Stat. 4669). Reclamation and the Basin States continue to recognize the entitlement and right of each State under existing law to use and develop the water of the Colorado River system.[5]

[5] Reclamation and the Basin States have exchanged letters and are in the process of amending the Contributors' funding agreement to, among other things, document and clarify the intent of the Parties consistent with the above disclaimer.

Appendix D1
Metrics Sub-Team Members

Appendix D1 – Metrics Sub-Team Members

The information presented in the *Technical Report D - System Reliability Metrics* is the outcome of a collaborative process involving representatives of numerous organizations.

A list of Metrics Sub-Team members (as of January 31, 2011) and their affiliations is presented below.

- Carly Jerla, Bureau of Reclamation
- Klint Reedy, Black & Veatch
- Martin Einert, Bureau of Reclamation
- Kara Gillon, Defenders of Wildlife
- Jason John, Navajo Nation
- Jan Matusak, The Metropolitan Water District of Southern California
- Colby Pellegrino, Southern Nevada Water Authority
- John Shields, Wyoming State Engineers Office
- Robert Wigington, The Nature Conservancy

Points of contact with other organizations that provided additional information (as of January 31, 2011) are listed below.

- Xavier Gonzalez, Western Area Power Administration
- Sam Loftin, Western Area Power Administration
- David Slick, Salt River Project
- Jack Barnett, Colorado River Basin Salinity Control Forum
- Robert Radtke, Bureau of Reclamation
- Katrina Grantz, Bureau of Reclamation
- Norm Henderson, National Park Service
- Bill Jackson, National Park Service
- Kent Turner, National Park Service
- Janet Bair, U.S. Fish and Wildlife Service
- Lesley Fitzpatrick, U.S. Fish and Wildlife Service
- Ted Kowalski, Colorado Water Conservation Board
- John Sanderson, The Nature Conservancy