RECLAMATION

Managing Water in the West

Colorado River Basin Water Supply and Demand Study

Technical Report A — Scenario Development

U.S. Department of the Interior
Bureau of Reclamation

December 2012

Mission Statements

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.

Colorado River Basin Water Supply and Demand Study

Technical Report A — Scenario Development

U.S. Department of the Interior
Bureau of Reclamation

December 2012

Contents

Tables

Figures

Appendix

Acronyms and Abbreviations

Basin	Colorado River Basin
Basin States	Colorado River Basin States
ESA	Endangered Species Act
GCM	General Circulation Model
Mexico	United Mexican States
Reclamation	Bureau of Reclamation
Study	Colorado River Basin Water Supply and Demand Study
tribes	federally recognized tribes

Technical Report A — Scenario Development

1.0 Introduction

The Colorado River Basin Water Supply and Demand Study (Study), initiated in January 2010, was conducted by the Bureau of Reclamation's (Reclamation) Upper Colorado and Lower Colorado regions, and agencies representing the seven Colorado River Basin States (Basin States) in collaboration with stakeholders throughout the Colorado River Basin (Basin). The purpose of the Study is to define current and future imbalances in water supply and demand in the Basin and the adjacent areas of the Basin States that receive Colorado River water over the next 50 years (through 2060), and to develop and analyze adaptation and mitigation strategies to resolve those imbalances. The Study contains for major phases to accomplish this goal: Water Supply Assessment, Water Demand Assessment, System Reliability Analysis, and Development and Evaluation of Options and Strategies for Balancing Supply and Demand.

Spanning parts of the seven states of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming, the Colorado River is one of the most critical sources of water in the western United States. The Colorado River is also a vital resource to the United Mexican States (Mexico). It is widely known that the Colorado River, based on the inflows observed over the last century, is over-allocated and supply and demand imbalances are likely to occur in the future. Up to this point, this imbalance has been managed, and demands have largely been met as a result of the considerable amount of reservoir storage capacity in the system, the fact that the Upper Basin States are still developing into their apportionments, and efforts the Basin States have made to reduce their demand for Colorado River water.

Concerns regarding the reliability of the Colorado River system to meet future needs are even more apparent today. The Basin States include some of the fastest growing urban and industrial areas in the United States. At the same time, the effects of climate change and variability on the Basin water supply has been the focus of many scientific studies which project a decline in the future yield of the Colorado River. Increasing demand, coupled with decreasing supplies, will certainly exacerbate imbalances throughout the Basin.

It is against this backdrop that the Study was conducted to establish a common technical foundation from which important discussions can begin regarding possible strategies to reduce future supply and demand imbalances. The content of this report is a key component of that technical foundation and describes the Study's scenario planning process.

The amount of water available and the progression of demand for water in the Basin (and the adjacent areas of the Basin States that receive Colorado River water) over the next 50 years are highly uncertain and dependent upon a number of socioeconomic and other factors. The potential impacts of future climate variability and climate change further contribute to these uncertainties. To analyze the future reliability of the Colorado River system, with and without adaptation and mitigation strategies, projections of water supply and demand were necessary. These projections needed to be sufficiently broad to capture the plausible ranges of uncertainty in future water supply and water demand to ensure that the reliability of the Colorado River system was adequately analyzed.

A scenario planning process was used to guide the development of scenarios that provided a broad range of projections of future water supply and demand. The process involved the identification of the key forces that will likely drive future water supply and water demand, ranking of the driving forces as to their relative importance and uncertainty, and use of the highly uncertain and highly important driving forces to identify various themes and storylines (narrative descriptions of scenarios) that describe how water supply and water demand may evolve in the future. Quantification of the storylines resulted in water supply and water demand scenarios that were used to assess future system reliability and assess the performance of options and strategies.

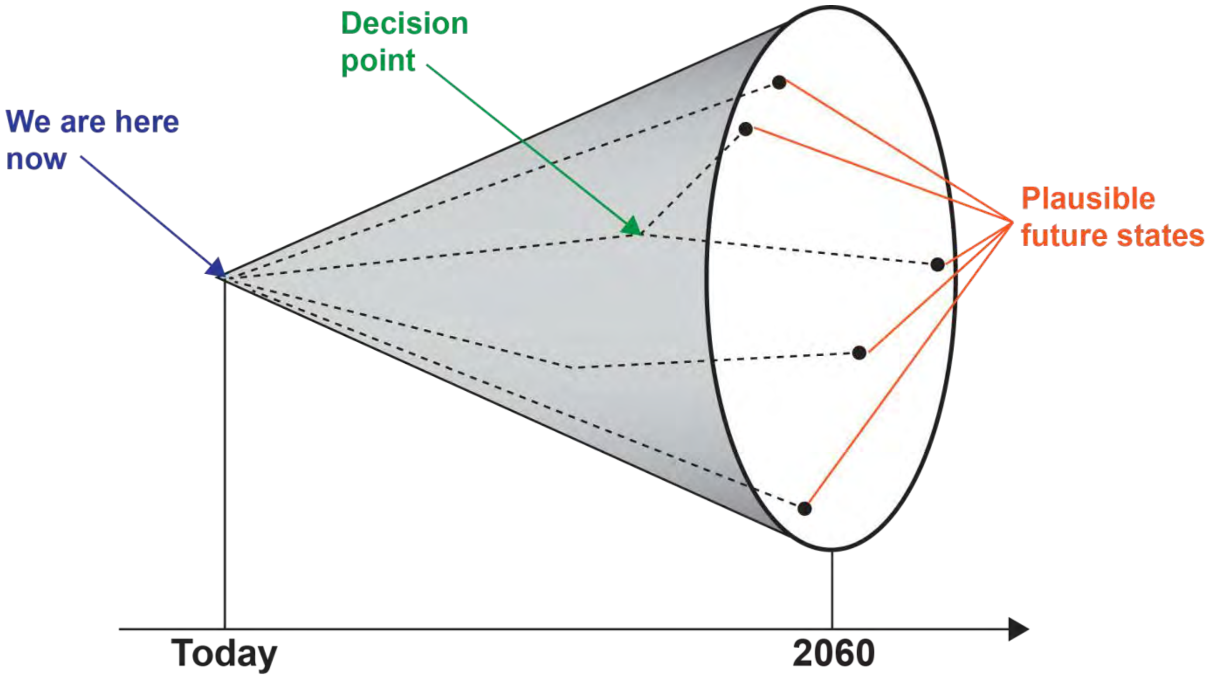
This report provides background on scenario planning and describes the scenario development approach used in the Study to develop the water supply and demand scenarios. Initially published in June 2011 under Interim Report No. 1, this report replaces the earlier publication. Four water supply scenarios and six water demand scenarios were identified and quantified. Details regarding the quantification and analysis of the water supply and water demand scenarios are presented in the respective technical reports (*Technical Report B – Water Supply Assessment,* and *Technical Report C – Water Demand Assessment*).

2.0 Incorporating Uncertainty in Water Resources Planning

Management of water resources, and particularly those of the Colorado River, is a complex interplay between natural and human systems, driven by forces such as climatic, demographic, economic, social, institutional, political, and technological factors. The precise trajectory of this interplay over time, and the resulting state of the physical system over time, are uncertain and cannot be represented by a single view of the future. In light of this broad uncertainty, scenario planning can be used to consider and portray the broad range of plausible futures in a manageable number of scenarios. Scenario approaches have been widely applied in water planning and management, from global to regional scales, although specific methodologies have varied considerably (Alcamo and Gallopin, 2003; Mara and Thomure, 2009; Water Utility Climate Alliance, 2010).

Scenarios are alternative views of how the future might unfold. Scenarios are not predictions or forecasts of the future. Rather, a set of well-constructed scenarios represents a range of plausible futures that assists in the assessment of future risks and the development of mitigation and adaptation options and strategies. Figure A-1 shows this concept. At present, there is an understanding of the current state of the Colorado River system. For the future, a range of plausible futures, represented by the funnel, can be identified. The suite of scenarios used in the planning effort should be sufficiently broad to span the plausible range.

FIGURE A-1
Conceptual Representation of the Uncertain Future of a System, also known as "The Scenario Funnel"
(adapted from Timpe and Scheepers, 2003)



3.0 Overview of Scenario Planning Process

Figure A-2 presents the general steps involved in the scenario planning process as applied to a water resources planning study, from the initial point of framing the focal question(s) being addressed by the study, through the development and analysis of options and strategies to improve system performance.

The shaded area within figure A-2 encapsulates the steps that are typically part of the development of scenarios, and are the focus of this report.

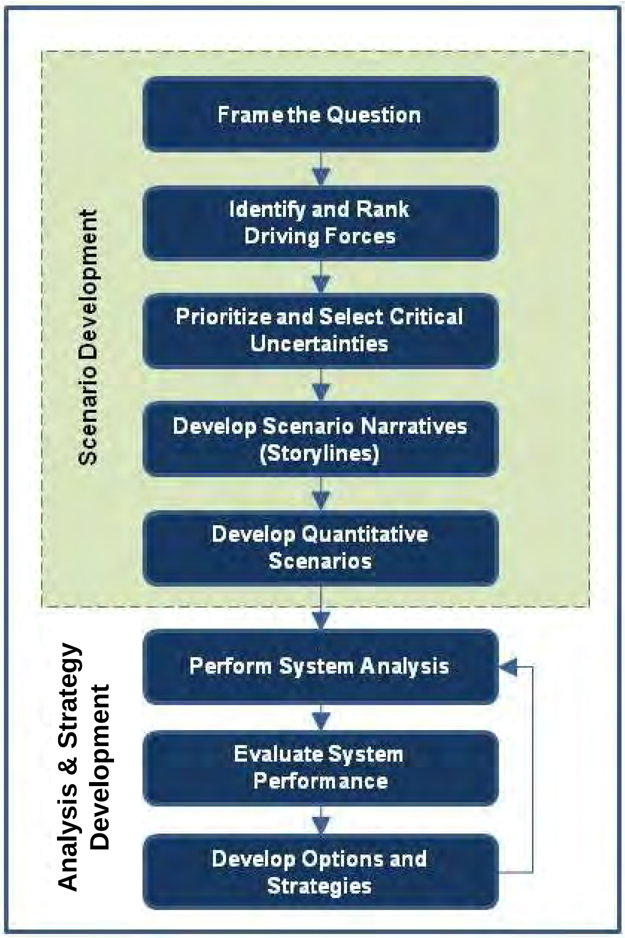
Input from a broad sampling of stakeholders, experts, and others interested in the management of the system was crucial throughout the development of scenarios. This input ensured that the resulting scenarios were representative of the plausible range of futures in the view of those who best know the system.

The five steps shown in figure A-2 for typical scenario development are described below.

3.1 Frame the Question

The scenario planning process begins with a clear understanding of the purpose and objectives of the planning study. Defining the focal question of the study is crucial to the development of scenarios and options and strategies. The focal question (or questions) is the key question or issue that the study wishes to address, and provides the framework for the consideration of the key forces that influence future uncertainty.

FIGURE A-2
General Steps Involved in the Scenario Planning Process



3.2 Identify and Rank Driving Forces

Driving forces are the factors that will likely have the greatest influence on the future state of the system and thereby the performance of the system over time. Although the driving forces that have been considered in water management studies have varied, driving forces within the following categories have generally been considered:

- Natural Systems
- Demographic
- Economic
- Technological
- Social
- Governance

Not all driving forces influence the system to the same degree or contribute the same level of uncertainty. In the development of scenarios, it is useful to rank each driving force based on its relative importance to the focal questions of the study and the relative degree of uncertainty of that driving force over time.

3.3 Prioritize and Select Critical Uncertainties

Critical uncertainties are the key driving forces that are identified as both highly uncertain and highly important. Stakeholder and other expert input is crucial for identifying these critical uncertainties to gauge the relative "importance" and "uncertainty" of each of the driving forces. This input can be gathered in various ways, such as holding workshops, conducting surveys, or using other outreach methods. The critical uncertainties can be identified from the expert input and other outreach, and a number of critical uncertainties are selected to form the basis for storyline development.

3.4 Develop Storylines

A storyline is the narrative description of a scenario, based on the critical uncertainties; the storyline provides the "plot" of the scenario. Development of storylines is a qualitative process, requiring the involvement of subject matter experts who have the best understanding of the system and of the critical uncertainties.

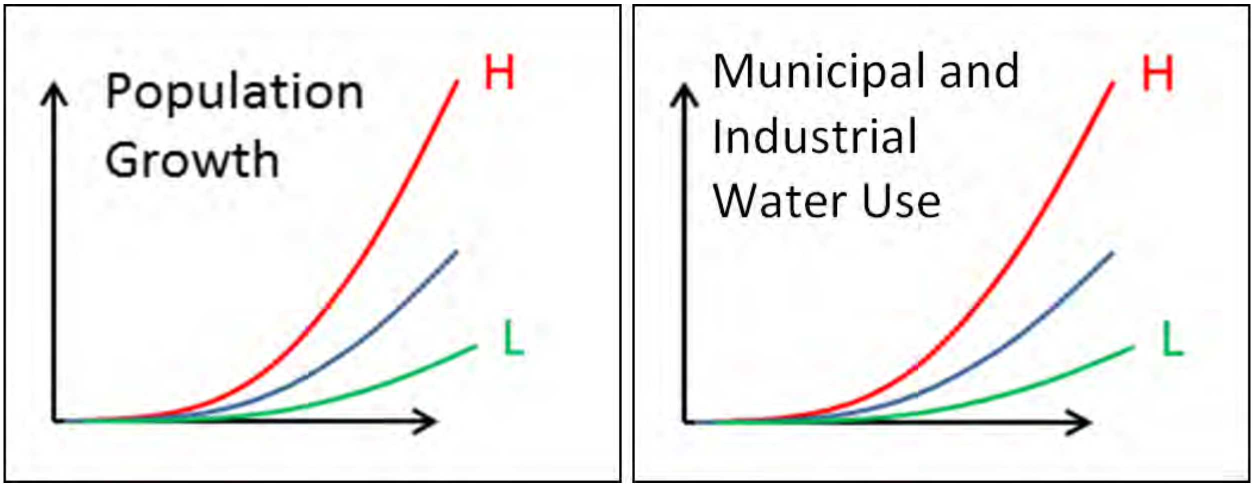
The process of developing the storylines requires identifying parameters that describe each critical uncertainty, characterizing the evolution of those parameters over time, and combining the characteristics of various parameters into descriptions of plausible futures.

Parameters are the variables that describe the behavior of a critical uncertainty. For example, for the critical uncertainty Changes in Population and Distribution, the parameters include "population" and "population distribution." Once the parameters have been identified, the plausible range of each parameter over time is described.

Figure A-3 shows a hypothetical high-, low-, and medium-growth curve for the key parameter, "population" on the left, and a similar hypothetical plot for the parameter, "municipal and industrial water use efficiency" parameter on the right. For each parameter, the curves represent qualitative characteristics describing plausible future trajectories. The two parameters in figure A-3 are descriptors of two separate critical uncertainties identified in the Study, Changes in Population Growth and Distribution and Changes in Municipal and Industrial Water Use Efficiency, respectively.

In the development of the storylines, the critical uncertainties and associated parameter characteristics are combined based on logical, coherent descriptions of how the future may unfold. For example, high population growth may be envisioned with modest or large increases in water use efficiency as part of a particular storyline. As a result of this process, the storyline and its logic should be understandable to a broad range of stakeholders. Furthermore, an understanding of the combination of parameter characteristics in a given storyline assists in the subsequent step of quantifying the scenario.

FIGURE A-3
Example of the Qualitative Characterization of Critical Uncertainties



3.5 Develop Quantitative Scenarios

Scenarios are the result of quantifying the parameter characteristics that are described in the storylines. As is the case with other steps in the scenario development process, stakeholder and other expert input is important to ensure that the resulting scenario depicts the appropriate range of each parameter as described in the storyline.

For example, in the case of population growth, there may be differing views as to what constitutes high, medium, and low growth. Dialogue is necessary to ensure a common understanding of the storyline's meaning and its subsequent quantification.

In some cases, scenarios make use of quantitative information previously developed to address uncertainties. In these cases, the existing information is reviewed and checked for consistency with the assumptions and storyline process.

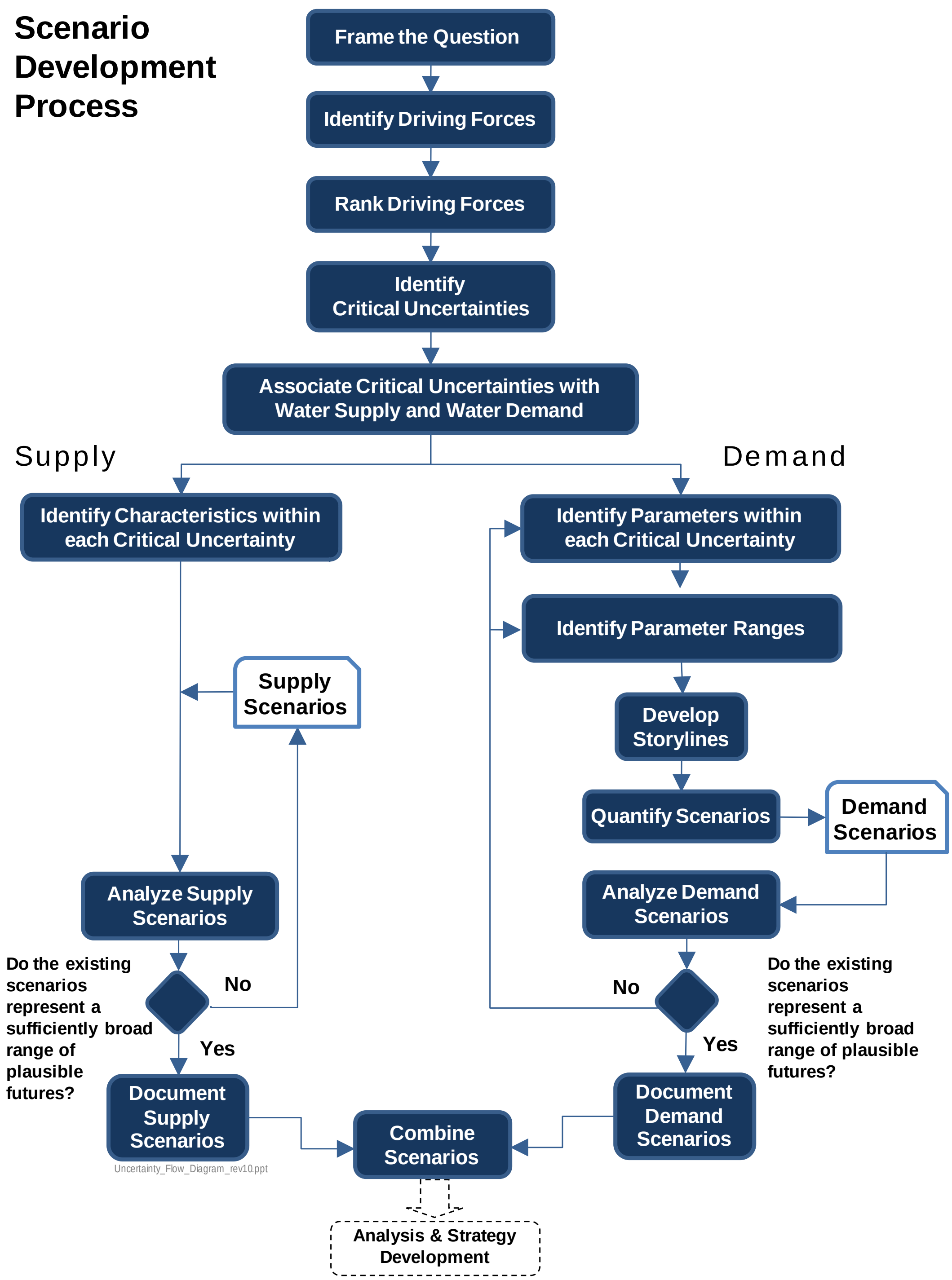
Well-understood and well-documented scenarios are critical to implementing the process depicted in figure A-2.

4.0 Implementation of Scenario Development Process

The general steps involved in scenario planning are shown in figure A-2, and they provided the framework for the approach implemented in the Study. To specifically address the needs of the Study, this approach was customized and is shown in figure A-4. This section describes the specific steps undertaken in the Study.

A collaborative process that engaged stakeholders was essential to the successful development of scenarios. For the Study, representatives of numerous organizations participated, including the Bureau of Reclamation (Reclamation), the Basin States, U.S. Fish and Wildlife Service, National Park Service, Bureau of Land Management, Western Area Power Administration, federally recognized tribes (tribes), conservation organizations, water delivery contractors, contractors for the purchase of federal power, and others interested in the Basin. This collaboration was accomplished through a variety of means, including workshops, surveys, and participation in sub-teams.

FIGURE A-4
Scenario Development Process Used in the Study



4.1 Frame the Question

The purpose and objectives defined in the *Plan of Study* (see *Study Report, Appendix 1 – Plan of Study*) were used to frame the focal questions that the Study addressed. These questions are:

1. What is the future reliability of the Colorado River system to meet the needs of Basin resources through 2060?
2. What are the options and strategies to mitigate future risks to these resources?

The first question requires an understanding of the underlying components of future reliability: water supply and water demand. Specifically, what factors determine the future availability of water and what factors that determine the future demand for water? The scenario development process addressed these questions and resulted in scenarios of the future that define a range of plausible water supply and water demand outcomes.

The second question relates to water management responses to mitigate and adapt to the potential impacts to Basin resources under scenarios of the future, and was the focus of the analysis and strategy development phases of the Study.

4.2 Identify Driving Forces

An initial list of 14 specific driving forces relevant to understanding potential future conditions was developed using the general categories previously described, based on experience managing the Colorado River system. Stakeholder teleconferences were conducted to seek input to refine and add to the initial list of driving forces. The stakeholder outreach was conducted by the Water Supply, Water Demand, and System Reliability Metrics Sub-Teams, and included members from water management entities, federal resource management agencies (fishery, recreation, energy, and land management), tribes, and conservation organizations. The input from these stakeholders expanded the initial list of driving forces from 14 to 18 and resulted in greater clarity in the definition of some driving forces. Table A-1 lists the driving forces. The numbers were assigned for identification purposes only and do not imply priority.

4.3 Rank Driving Forces

Stakeholder and other expert input regarding the critical uncertainties was collected by conducting a survey (see appendix A1). The survey listed the 18 driving forces (table A-1) and asked the respondents to independently rate (using a scale of 1 through 5, with 5 being the highest) the relative importance and relative uncertainty associated with each driving force. Specifically, the respondents were asked to provide ratings based on the following two characteristics:

- **Importance (1 through 5)**: Rate the relative importance of the driving forces to the reliability of the Colorado River system to meet the needs of Basin resources through 2060
- **Uncertainty (1 through 5):** Rate the relative uncertainty of the driving forces in the Colorado River Basin through 2060

TABLE A-1
List of Driving Forces Influencing Future Colorado River System Reliability

No.	Driving Force
1	Changes in streamflow variability and trends
2	Changes in climate variability and trends (e.g., temperature, precipitation, etc.)
3	Changes in watershed conditions (e.g., diseases, species transitions, etc.)
4	Changes in population and distribution
5	Changes in agricultural land use (e.g., irrigated agricultural areas, crop mixes, etc.)
6	Changes in urban land use (e.g., conversion, density, urbanization, etc.)
7	Changes in public land use (e.g., forest practices, grazing, wilderness areas, etc.)
8	Changes in agricultural water use efficiency
9	Changes in municipal and industrial water use efficiency
10	Changes in institutional and regulatory conditions (e.g., laws, regulations, etc.)
11	Changes to organization or management structures (e.g., state, federal, bi-national institutions)
12	Changes in water needs for energy generation (e.g., solar, oil shale, thermal, nuclear, etc.)
13	Changes in flow-dependent ecosystem needs for Endangered Species Act (ESA)-listed species
14	Changes in other flow-dependent ecosystem needs
15	Changes in social values affecting water use
16	Changes in cost of energy affecting water availability and use
17	Changes in water availability due to tribal water use and settlement of tribal water rights claims
18	Changes in water quality including physical, biological, and chemical processes

The respondents were encouraged to provide comments related to each response to aid in understanding the context of high or low responses. In addition, guidance was provided to the respondents relating to the first focal question and to the Study period (through 2060), consideration of current and evolving trends, and external versus internal factors.

The survey was sent to all who participated in the driving forces list review and refinement. Some entities sought further input from their respective technical staffs and/or stakeholders. Respondents could respond to the survey anonymously, if desired, but their respective affiliation category was entered into a database. A total of 51 survey responses were received, with the affiliation category distribution as shown in table A-2. Water management entities comprised more than half of the responses, and conservation organizations, fishery management entities, and recreation entities represented approximately one-third of the responses.

TABLE A-2
Summary of Respondent Affiliation Category for the Driving Force Uncertainty Survey

Respondent Category	No. of Responses Received
Water Management Entities (including Reclamation)	28
Conservation Organizations	9
Fishery Management Entities	3
Federally Recognized Tribes and Communities	3
Water Resources Contractors	3
Recreation Management Entities	2
Energy Management Entities	2
Land Management Entity	1
Total	**51**

The individual survey responses were compiled into a database, and the mean and standard deviation were computed for each driving force, as shown in table A-3. Driving forces that had the highest mean responses were classified as highly important and highly uncertain. The driving forces, "changes in streamflow variability and trends" (No. 1) and "changes in climate variability and trends" (No. 2), consistently ranked high in both importance and uncertainty. Similarly, "changes in population and distribution" (No. 4), consistently ranked high in importance. Although the sample size was relatively small for evaluating statistics, the standard deviation provided a measure of the differences in responses among the respondents. "Changes in streamflow variability and trends" (No. 1) was considered important by most respondents, as represented by a small standard deviation, whereas "changes in institutional and regulatory conditions" (No. 10) and "changes to organization or management Structures" (No. 11) had a wide range of responses in both importance and uncertainty.

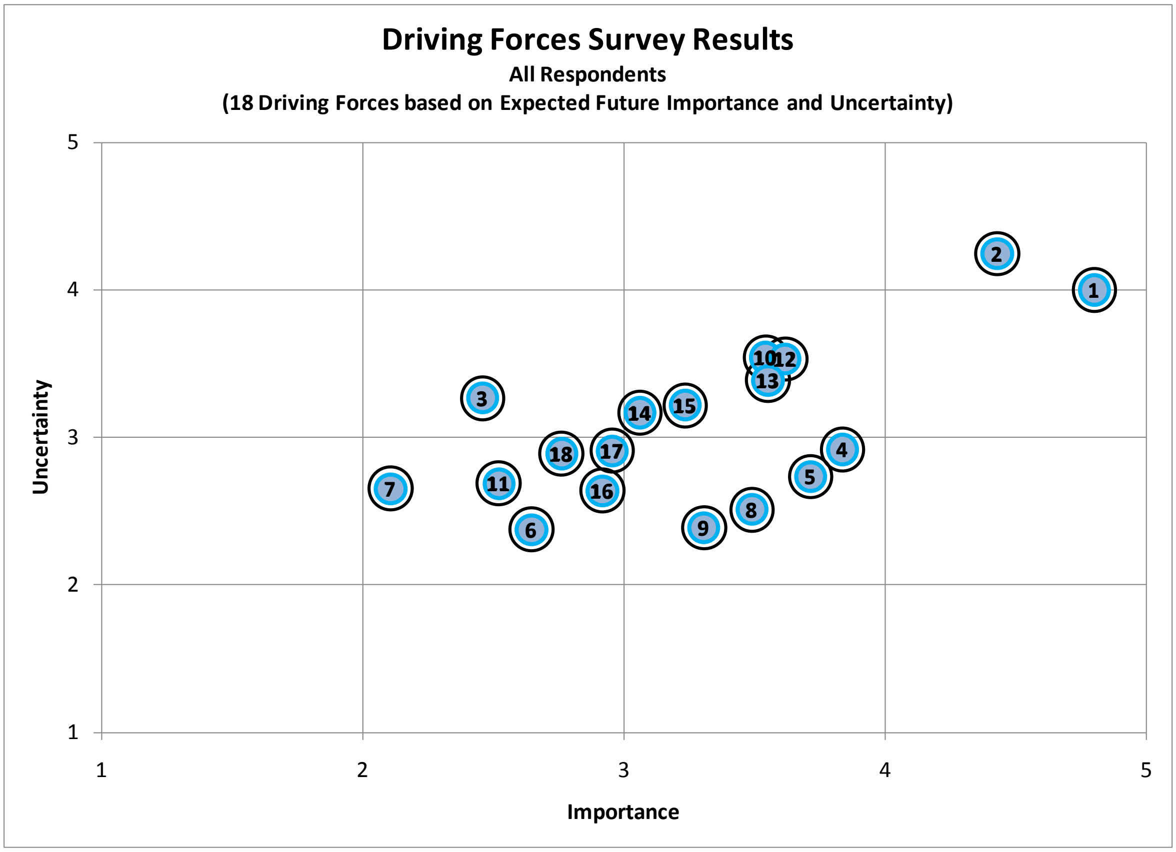
The results of the survey are also displayed in figure A-5. In this figure, the numbers are the driving forces listed in table A-1 and the plotting position is determined by the relative importance and relative uncertainty based on the mean of all survey responses. Driving forces that plotted to the upper right were believed to be highly important and highly uncertain, and those that plotted to the lower left were perceived by the respondents to be of lesser importance and lower uncertainty. The driving forces that plotted to the lower right were perceived to be of high importance, but had less uncertainty.

TABLE A-3
Summary of Responses for the Driving Forces Survey[1]

No.	Driving Force	Importance		Uncertainty	
		Mean	Std Dev	Mean	Std Dev
1	Changes in streamflow variability and trends	4.80	0.53	4.00	1.12
2	Changes in climate variability and trends (e.g., temperature, precipitation, etc.)	4.43	0.94	4.24	1.01
3	Changes in watershed conditions (e.g., diseases, species transitions, etc.)	2.46	1.10	3.27	0.88
4	Changes in population and distribution	3.84	0.96	2.92	1.08
5	Changes in agricultural land use (e.g., irrigated agricultural areas, crop mixes, etc.)	3.71	1.17	2.73	1.00
6	Changes in urban land use (e.g., conversion, density, urbanization, etc.)	2.65	0.96	2.38	1.02
7	Changes in public land use (e.g., forest practices, grazing, wilderness areas, etc.)	2.11	0.94	2.65	0.99
8	Changes in agricultural water use efficiency	3.49	1.19	2.51	0.87
9	Changes in municipal and industrial water use efficiency	3.31	1.12	2.39	0.84
10	Changes in institutional and regulatory conditions (e.g., laws, regulations, etc.)	3.54	1.24	3.54	1.25
11	Changes to organization or management structures (e.g., state, federal, bi-national institutions)	2.52	1.25	2.69	1.22
12	Changes in water needs for energy generation (e.g., solar, oil shale, thermal, nuclear, etc.)	3.62	1.11	3.53	1.08
13	Changes in flow-dependent ecosystem needs ESA-listed species	3.55	1.00	3.39	1.11
14	Changes in other flow-dependent ecosystem needs	3.06	1.13	3.17	1.19
15	Changes in social values affecting water use	3.23	1.22	3.22	1.23
16	Changes in cost of energy affecting water availability and use	2.92	1.16	2.64	1.22
17	Changes in water availability due to tribal water use and settlement of tribal water rights claims	2.95	1.18	2.91	1.05
18	Changes in water quality, including physical, biological, and chemical processes	2.76	1.25	2.89	1.27

[1] Respondent survey rating scale of 1 to 5, with 5 being the highest.

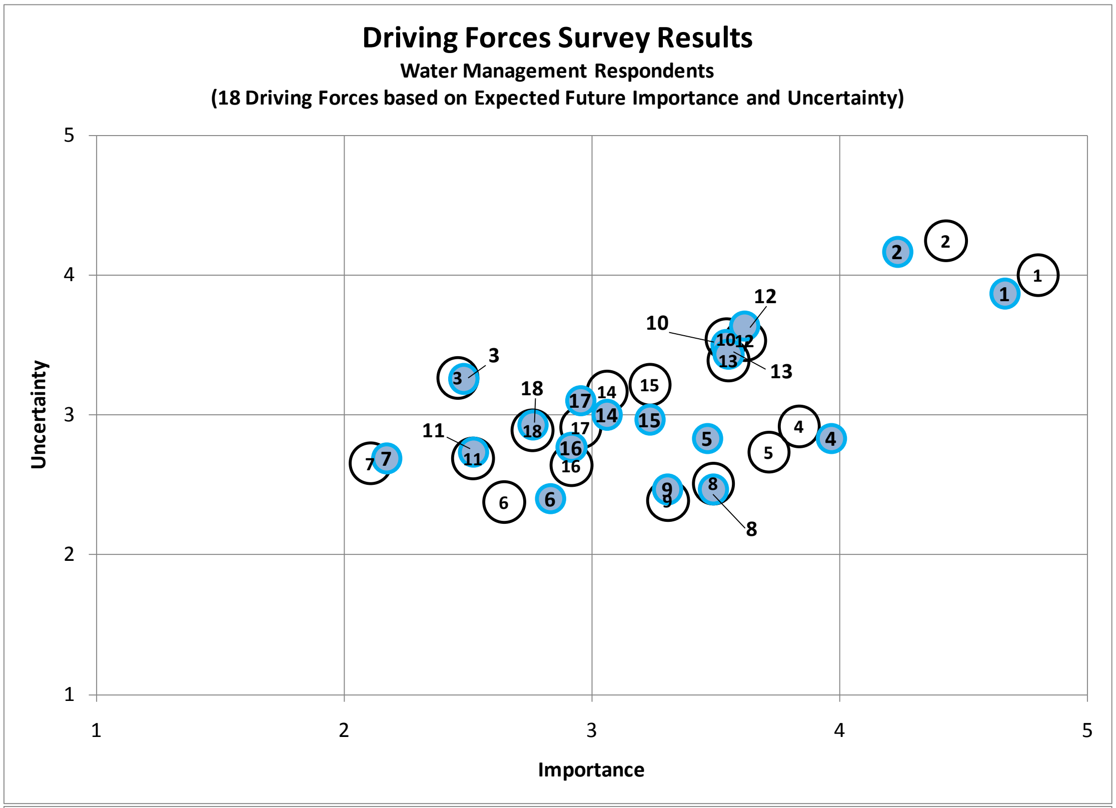
FIGURE A-5
Plot of Mean Results from Driving Forces Survey

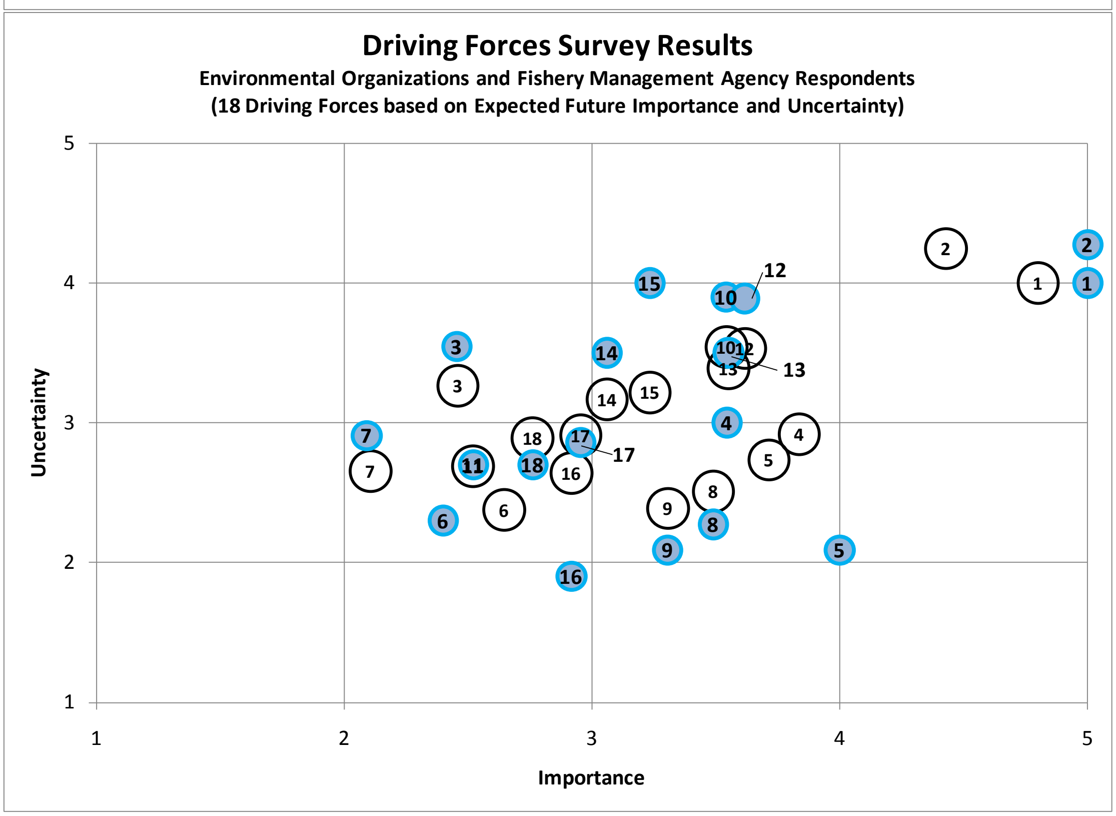


Because of the differences in the number of respondents among groups, results based on particular respondent groups were evaluated. Figure A-6 represents the results from water management entity respondents (top) and the results from the conservation organizations and fishery management entities (bottom). In this figure, the hollow circles represent the ranking based on all responses, and the shaded circles represent the responses from the particular respondent group.

While the sample sizes were small when partitioning in this fashion, there was a strong commonality of the results among these groups. For example, both respondent groups rated the streamflow variability (No. 1) and climate change (No. 2) driving forces as the highest, despite differences in absolute scores. Similarly, water needs for energy generation (No. 12) and flow-dependent needs for ESA-listed species (No. 13) were rated highly important and highly uncertain by both groups.

FIGURE A-6
Plot of Mean Results from Driving Forces Survey Water Management Respondents (top, 31 respondents), and Environmental Organizations and Fishery Management Agencies (bottom, 12 respondents)



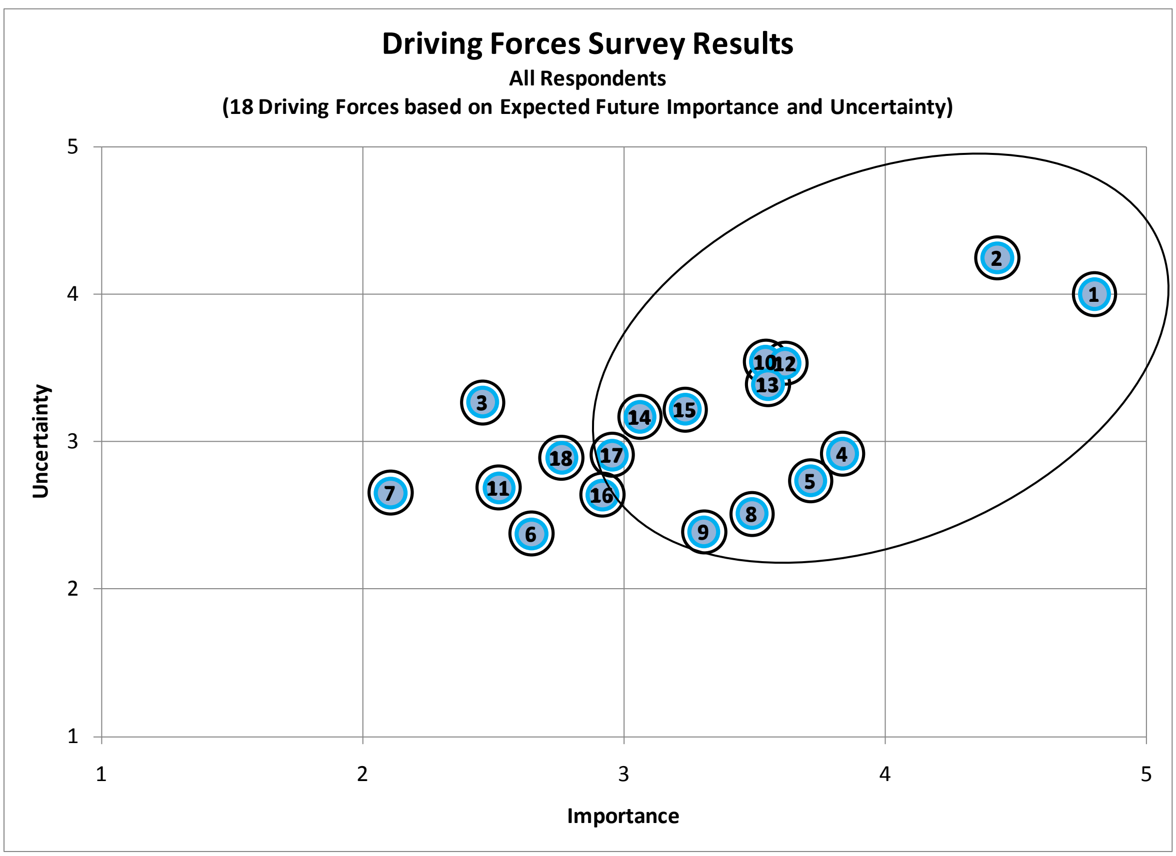


4.4 Identify Critical Uncertainties

Consideration of the relative rankings based on the survey responses led to identification of the critical uncertainties, as shown in the oval in figure A-7. The driving forces that were obviously located in the upper right in the figure were selected as critical uncertainties. For the driving forces near the middle of the graph, judgment and expertise were used to decide whether they should be considered as critical uncertainties.

The initial list of critical uncertainties was checked to see if the results would have been different based on responses of individual respondent groups. Although there were some differences in terms of the relative magnitude of the ratings, it was concluded that the driving forces representing the critical uncertainties would not be different based on subsets of the survey responses. In general, the decision was made to be more inclusive, and the oval was expanded to include several of the driving forces in the middle range.

FIGURE A-7
Plot of Mean Results from Driving Forces Survey and Selected Critical Uncertainties



4.5 Associate Critical Uncertainties with Water Supply and Water Demand

Water supply and water demand are the key factors affecting the future reliability of the Colorado River system. Although critical uncertainties may affect both supply and demand, each critical uncertainty was associated with the factor thought to be most affected. For critical uncertainties that have significant impact to both supply and demand, adjustments to parameters affecting both water supply and water demand were made.

The critical uncertainties were first grouped by the broader categories of driving forces. Then each driving force category was aligned with either water supply or water demand, depending on its anticipated area of greatest influence. The resulting association of critical uncertainties is shown in table A-4. The alignment of driving forces into water supply or water demand was performed to provide focus to the evaluation of the driving force, but the subsequent quantification of scenarios considered important linkages across water supply and water demand. For example, although changes in climate variability and trends will affect water demand (primarily through increased evapotranspiration due to increase in temperature), the potential influence is considered greater on water supply. For scenarios that explicitly included climate change, the associated demands were adjusted based on temperature-related effects on evapotranspiration (see *Technical Report C – Water Demand Assessment*).

TABLE A-4
Association of Critical Uncertainties with Key Factors in System Reliability

Key Basin Study Driving Forces Identified in Survey	General Driving Force Category	Key Factor In System Reliability Most Affected
Changes in streamflow variability and trends [No. 1] Changes in climate variability and trends (e.g., temperature, precipitation, etc.) [No. 2]	Natural Systems (Hydroclimate)	Water Supply
Changes in population and distribution [No. 4] Changes in agricultural land use (e.g., irrigated agricultural areas, crop mixes, etc.) [No. 5]	Demographics and Land Use	Water Demand
Changes in agricultural water use efficiency [No. 8] Changes in municipal and industrial water use efficiency [No. 9] Changes in water needs for energy generation (e.g., solar, oil shale, thermal, nuclear, etc.) [No. 12]	Technology and Economics	Water Demand
Changes in institutional and regulatory conditions (e.g., laws, regulations, etc.) [No. 10] Changes in flow-dependent ecosystem needs for ESA-listed species [No. 13] Changes in other flow-dependent ecosystem needs [No. 14] Changes in social values affecting water use [No. 15] Changes in water availability due to tribal water use and settlement of tribal water rights claims [No. 17]	Social and Governance	Water Demand

4.6 Develop Water Supply and Water Demand Scenarios

After determining the associations of the critical uncertainties to the key factors of water supply and demand, additional stakeholder and subject matter expertise was sought to complete the scenario development process through the Water Supply and Water Demand Sub-Teams. Each sub-team had different requirements and therefore followed different steps, as shown in figure A-4. These steps are discussed in *Technical Report B – Water Supply Assessment* and *Technical Report C – Water Demand Assessment*, respectively.

The following scenarios were considered in the Study:

Water Supply Scenarios

- Observed Resampled
- Paleo Resampled
- Paleo Conditioned
- Downscaled General Circulation
- Model (GCM) Projected

Water Demand Scenarios

- Current Projected (A)
- Slow Growth (B)
- Rapid Growth (C1 and C2)
- Enhanced Environment (D1 and D2)

The themes associated with each scenario are described below.

The water supply scenarios were focused around the key driving forces in the "natural systems" category. These driving forces relate primarily to streamflow variability and trends, and climate variability and trends. Reclamation has conducted research and development relating to the uncertainty of future hydrologic conditions, and these previous efforts were incorporated to the extent possible. The water supply scenarios used significant information from the observed record of streamflow, reconstructions of streamflow from tree-ring records, and projections of future hydroclimate conditions using downscaled global climate model results. The themes associated with the water supply scenarios are:

- **Observed Record Trends and Variability (Observed Resampled):** Future hydrologic trends and variability are similar to the past approximately 100 years.

- **Paleo Record Trends and Variability (Paleo Resampled):** Future hydrologic trends and variability are represented by reconstructions of streamflow for a much longer period in the past (nearly 1,250 years) that show expanded variability.

- **Observed Record Trends and Increased Variability (Paleo Conditioned):** Future hydrologic trends and variability are represented by a blend of the wet-dry states of the longer paleo-reconstructed period (nearly 1,250 years), but magnitudes are more similar to the observed period (about 100 years).

- **Downscaled GCM Projected Trends and Variability (Downscaled GCM Projected):** Future climate will continue to warm, with regional precipitation and temperature trends represented through an ensemble of future downscaled GCM projections and simulated hydrology.

The assumptions, methods, and results for each of these water supply scenarios are discussed in detail in *Technical Report B – Water Supply Assessment*.

The water demand scenarios were focused on the driving forces related to the general driving force categories, of "demographics and land use," "technology and economics," and "social and governance." The Water Demand Sub-Team identified the parameters that most significantly influence each critical uncertainty within the demand-focused categories. The range of parameter characteristics and the logical combinations of those characteristics were explored by the Water Demand Sub-Team, resulting in the following themes:

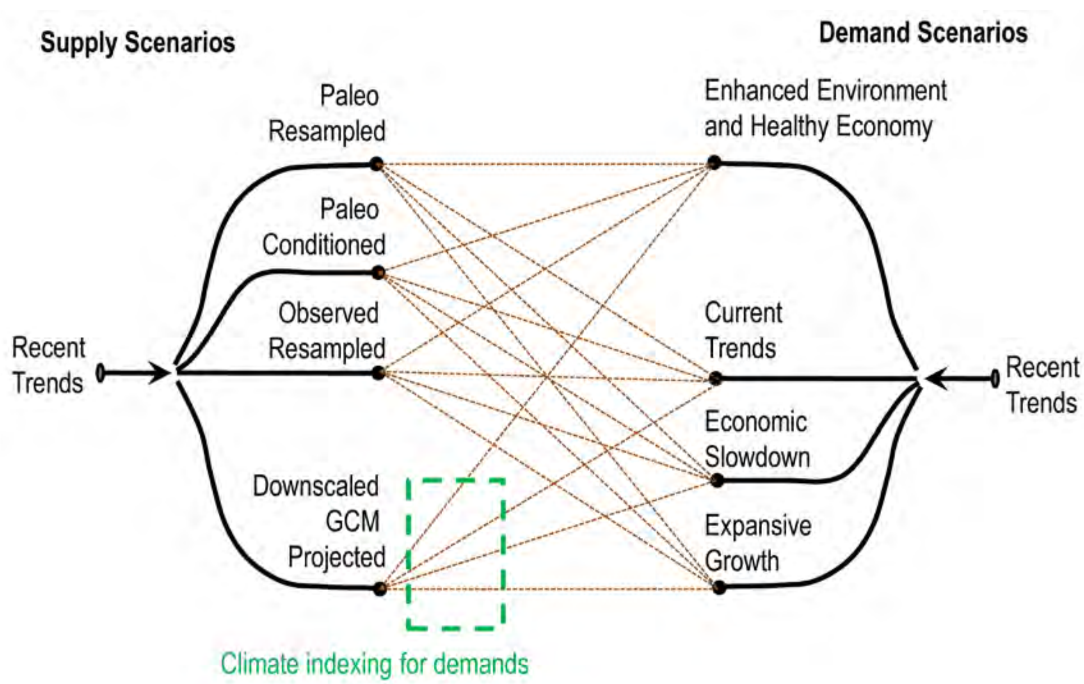
- **Current Projected (A):** Growth, development patterns, and institutions continue along recent trends
- **Slow Growth (B)**: Slow growth with emphasis on economic efficiency
- **Rapid Growth (C1 and C2)**: Economic resurgence (population and energy) and current preferences toward human and environmental values
- **Enhanced Environment (D1 and D2)**: Expanded environmental awareness and stewardship with growing economy

The assumptions, methods, and storylines for each of the water demand scenarios are discussed in detail in *Technical Report C – Water Demand Assessment*.

5.0 Conclusions

To assess the future reliability of the Colorado River system, the water supply and water demand scenarios were combined to yield scenarios for both supply and demand, as depicted in figure A-8 and described in detail in *Technical Report A – Water Supply Assessment* and *Technical Report B – Water Demand Assessment*. Each water supply scenario, relating primarily to the driving forces of streamflow and climate variability and trends, was combined with each water demand scenario, relating to "demographics and land use," "technology and economics," and "social and governance" driving forces to capture a more-complete description of the range of future uncertainty influencing the Colorado River system. All combinations of water supply and water demand scenarios were used to assess system reliability for a sufficiently broad range of plausible futures.

FIGURE A-8
Illustration of Combined Water Supply and Water Demand Scenarios



6.0 References

Alcamo, J. and Gallopin, G. 2009. *United Nations World Water Assessment Programme, Building a 2nd Generation of World Water Scenarios*.

Mara, R. and T. Thomure. 2009. "Scenario Planning: Making Strategic Decisions in Uncertain Times." *Southwest Hydrology*. May/June.

Timpe, C. and M.J.J. Scheepers. 2003. *SUSTELNET: A Look into the Future: Scenarios for Distributed Generation in Europe*.

Water Utility Climate Alliance. 2010. *Decision Support Planning Methods: Incorporating Climate Change Uncertainties into Water Planning*.

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 the 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 was constrained by funding, timing, and technological and other limitations, and in some cases presented 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 developed and incorporated assumptions to further complete the Study. Where possible, a range of assumptions was typically used to identify the sensitivity of the results to those assumptions.

Nothing in the Study, however, is intended for use against any Basin State, any federally recognized tribe, 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, any federally recognized tribe, federal government or Upper Colorado River Commission as it relates to the Law of the River. Furthermore, nothing in the Study is intended to, nor shall the Study be construed so as to, interpret, diminish or modify the rights of any Basin State, any federally recognized tribe, 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, or Minute No. 319 of November 20, 2012, 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) as amended, the Hoover Power Plant Act of 1984 (98 Stat. 1333), the Colorado River Floodway Protection Act (100 Stat. 1129; 43 U.S.C. 1600), the Grand Canyon Protection Act of 1992 (Title XVIII of Public Law 102-575, 106 Stat. 4669), or the Hoover Power Allocation Act of 2011 (Public Law 112-72). In addition, nothing in the Study is intended to, nor shall the Study be construed so as to, interpret, diminish or modify the rights of any federally recognized tribe, pursuant to federal court decrees, state court decrees, treaties, agreements, executive orders and federal trust responsibility. Reclamation and the Basin States continue to recognize the entitlement and right of each State and any federally recognized tribe under existing law, to use and develop the water of the Colorado River system.