Chapter 5  Managing for an Uncertain Future

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Chapter 5  Managing for an Uncertain Future

About This Chapter
Chapter 5, *Managing for an Uncertain Future*, is based on the need for decision-makers and water and resource managers and planners to use the best available data and analytical tools in planning for California’s water future in the face of many uncertainties and risks. It provides examples of uncertainties and discusses the need to consider risks in planning for a more sustainable future. The chapter presents an approach for these evaluations and examples of what was learned during preparation of this Water Plan Update to identify the types of investments that may be useful for a more sustainable future.

- Planning Approach
- Recognizing and Reducing Uncertainty
- Assessing Risk
- Managing for Sustainability
- Example 2050 Analysis for this Water Plan
- Summary

Planning Approach

Overview
Update 2005 included a framework for improving water reliability through two initiatives. One initiative placed emphasis on integrated regional water management to make better use of local water sources by integrating multiple aspects of managing water and related resources such as water quality, local and imported water supplies, watershed protection, wastewater treatment and recycling, and protection of local ecosystems. The second initiative placed emphasis on maintaining and improving statewide water management system.

These two initiatives are still at the root of the strategic plan in Update 2009 to secure reliable and clean water supplies through 2050. Like the last Water Plan, Update 2009 acknowledges that planning for the future is uncertain and that change will continue to occur. Update 2009 enhances the effectiveness of the two initiatives by incorporating three key considerations into the planning approach for future management of these regional and statewide systems. The planning approach should (1) recognize and reduce uncertainties inherent in the system, (2) define and assess the risks that can hamper successful system management and select management practices that reduce the risks to acceptable levels, and (3) keep an eye towards approaches that help sustainability of the resources and water and flood systems.

This chapter provides a general description of this planning approach. Chapter 6, *Integrated Data and Analysis*, provides more detail on the analysis and findings.

PLACEHOLDER Box 5-1 Uncertainty, Risk, and Sustainability
Old Planning Approach – The Past is a Model for the Future

Water managers have always recognized the variable water flow in California’s streams and rivers during wet and dry periods spanning seasons to multiple years. Having too little water or too much water, droughts or floods, were often the main reasons that Californians built early water projects. Early in California’s water development history, personal observations and experience were often the best data available to help size water facilities because recorded data records did not exist.

A system to record water flow conditions over time gradually improved data available to water managers. However, the main assumption governing water management for much of California’s history has been that past records were a good indication of the frequency, duration, and severity of future floods and droughts, and these were used as models of potential future conditions. In addition, historical records were generally used to establish trends, such as population growth, that were assumed to continue into the future.

This static view of the range of possible future conditions worked fairly well when the demands on the resources were considerably lower than now. Early designers may have thought they understood the range of streamflows that could occur and the likelihood that a reservoir would refill in a given year, but generally did not fully understand the interrelationships among ecosystem issues, water availability issues, water use issues, water quality issues.

In addition, risks posed by earthquakes, extreme floods, and extreme droughts were generally underestimated. Without a fuller acknowledgement of the uncertainties inherent in the system and the risks that the system actually faced, the system management was relatively simple compared with today’s standards. Conditions appeared more certain and less risky than they actually were. While understanding the past is still an important part of managing for the future, it is becoming increasingly apparent that continued management under this old approach will not provide for sustainable water resources into the future.

New Planning Approach – Anticipate Change

Today, as part of integrated regional water management and integrated flood management, California’s water and resource managers must recognize that conditions are changing and that they will continue to change. Traditional approaches for predicting the future based solely on projecting trends will no longer work. Today, there is better understanding that strategies for future water management must be dynamic, adaptive, and durable. In addition, the strategies must be comprehensive and integrate physical, biological, and social sciences.

California’s water management system is large, complex, and requires a great deal of cooperation and collaboration among decision-makers at all levels of State, federal, regional, and local entities. The California Water Plan Update 2005 stressed the importance of a common analytical approach for these entities to understand and manage the system, especially when management actions may compete for the same resources. The entities must make sound investments that balance risk with reward, given today’s uncertainties and those that may occur in the future. Update 2005 also emphasized the benefits of integrated regional water management. Now, Update 2009 adds integrated flood management as part of overall integrated water management.

As part of this and future California Water Plan updates, the Water Plan is promoting ways to develop a common approach for data standards and for understanding, evaluating, and improving regional and statewide water management systems, and for common ways to evaluate and select
from alternative management strategies and projects. DWR will develop the Water Plan Information Exchange (Water PIE) for accessing and sharing data and networking existing databases and websites, using GIS software to improve analytical capabilities and developing timely surveys of statewide land use, water use, and estimates of future implementation of resource management strategies.

The new approach incorporates consideration of uncertainty, risk, and sustainability into planning for the future:

1) **Uncertainty.** There are enormous uncertainties facing water managers in planning for the future. How water demands will change in the future, how ecosystem health will respond to human use of water resources, what disasters may disrupt the water system, and how climate change may affect water availability, water use, water quality, and the ecosystem are just a few uncertainties that must be considered. More information on uncertainties can be found later in this chapter and in Volume 4 Reference Guide article titled, “_________.

The goal is to recognize existing uncertainties, anticipate future uncertainties, and to reduce the uncertainties to the extent possible. Uncertainties will never be eliminated, but better data collection and management and improved analytical tools will allow water and resource managers to better understand risks within the system. Chapter 6, Integrated Data and Analysis, provides a more detailed description of methods to evaluate how uncertainty can be reduced.

2) **Risks.** Each undesirable event has a certain chance of occurring and a set of consequences should it occur. For example, a chance of a levee failure with a certain sized flood event can be estimated with associated economic and human consequences. Likewise, a specific severity of drought may occur on average of once during a 30-year period and carry economic consequences of many billions of dollars.

By reducing the uncertainties described above, the “true” risks can be better understood. State government and other entities are performing more risk assessments that can be used in future planning to balance risk with reward from new management actions. Risk assessments are also a way to quantitatively consider the uncertainties that relate to events of interest such as the performance of levees, the consequences of flooding, and the impact of events on the environment. More information on these risk assessments can be found in a subsection later in this chapter.

3) **Sustainability.** Given the uncertainties and risks in the water system, some management strategies may provide for a more sustainable water supply and flood management systems, and ecosystems than another set of management strategies. Recognizing that change will continue to occur and that additional uncertainties and risks are likely to surface in the future, water management must be dynamic, adaptive, and durable.

This Water Plan considers three potential future scenarios as a way to deal with uncertainty and risk and to improve resource sustainability. One scenario is a projection of current trends. Another scenario considers lower population growth and other factors that may require less intensive use of resources. A third scenario covers the possibility of more expansive population growth and other factors that would result in more intensive use of resources. The concept is to not plan for any one given future as in past water plan updates, but to look at how each future scenario could be managed. Certain combinations
of management strategies, or response packages, may prove to be appropriate regardless of the future conditions. This is especially true if the response packages have a degree of adaptability to differing conditions that may develop. A general description of the scenarios can be found in a subsection later in this chapter. Detailed information of the scenarios and the response packages can be found in Chapter 6.

In order for any response package to provide for sustainable resource use, indicators of success need to be defined, monitored, and results analyzed periodically.

**Recognizing and Reducing Uncertainty**

There are two broad types of uncertainty:

- The first type of uncertainty is from the inherent randomness of events in nature such as the occurrence of an earthquake or a flood. This type of uncertainty is known as aleatory uncertainty and cannot be reduced by collection of additional data. However, additional data may allow better quantification of aleatory uncertainty.

- The second type of uncertainty can be attributed to lack of knowledge or scientific understanding. This type of uncertainty is known as epistemic (knowledge-based) uncertainty. In principle, epistemic uncertainty can be reduced with improved knowledge that comes from collection of additional information.

Although it is not necessary to categorize uncertainty for the Water Plan update into these two types of uncertainty, it is important to improve data collection and analytical tools to better understand the uncertainty.

California’s water and resource managers must deal with a broad range of uncertainty. Uncertainty is inherent in the existing system and in all changes that may occur in the future. One simple example of this is that water managers can be certain that the flows in California’s rivers will be different next year compared with this year, but the uncertainty lies in not knowing the magnitude or timing of those changes. The threat of a chemical spill that may disrupt water diversion presents uncertainty. Future protections for endangered species may require modifications in water operation procedures that are unknown today. There are many uncertainties about how the system functions today. For example, scientists are trying to understand the reasons for the pelagic fish decline in the Delta, the condition of levee foundations, and the extent of groundwater recharge and overdraft to name a few.

For the purposes of considering potential future changes and their inherent uncertainties, it is useful to consider how change may occur; gradual changes over the long-term or short-term, including sudden changes. Gradual changes can include things like variation in population by region, shifts in the types and amount of crops grown in an area, or changes in precipitation patterns or sea level rise. Sudden changes can include episodic events such as earthquakes, floods, droughts, equipment failures, chemical spills, or intentional acts of destruction. The nature of these changes, the uncertainties about their occurrence, and their potential impacts on water management systems can have big influences on how to respond to the changes.

Figure 5-1 shows some sources of future change and uncertainty. Also, the Volume 4 Reference Guide, provides more discussion on each of these sources of future change and uncertainty.
Assessing Risk

With improved understanding of uncertainties, risks facing future operation of the system can be better assessed. Most risks originate from hazards like floods, earthquakes, droughts, but risks can also be due other issues like water demands growing faster than anticipated, salt water intrusion, or ecosystem problems for example. DWR defines risk as the probability that some undesirable event will occur, which is usually linked with a description of the corresponding consequences of that event, or:

Risk = the probability of the occurrence (times) the consequences of the occurrence

For example, for a flooding hazard:

- Probability equals the frequency of the storm event that causes a levee to fail, say 1 percent chance each year.
- Consequences equal the effects of the floodwater from the levee failure upon the human and natural environment; say $100 million in damages.
- The annual risk would be 0.01 X $100 million, or $1 million per year.

Figure 5-2 further demonstrates risk for flooding from a levee failure.

PLACEHOLDER Figure 5-2 Understanding flood risks

Accounting for Risk

Although it is impossible to account for all sorts of uncertainty and risk in a planning study, there are techniques that can be used to acknowledge their existence and to assign some quantitative importance to them in the analysis. These techniques include direct enumeration, sensitivity analysis, scenario analysis, probability analysis, game theory, and in some cases, stochastic simulation. Planners may combine analyses, such as performing scenario analysis supported by probability analysis.

- **Direct enumeration.** With this technique, all possible outcomes are listed. While this would provide decision-makers an idea of the possible outcomes of an action, it doesn’t provide any clue as to the probability of one event happening over another. Also, given the complex relationships that are involved in most water resource related studies, all possible outcomes are not likely to be known.

- **Sensitivity, or scenario, analysis.** In sensitivity analysis, the values of key variables can be varied to test their effects upon the variables being analyzed. The variables can be tested one at a time to find ones that have a significant impact on the results and those that don’t. An example of this would be to vary the assumption about future energy costs. If different energy costs do not have a significant effect upon the relative ranking of the proposed project relative to its alternatives, the analyst may feel more comfortable with the project. Although sensitivity analysis is relatively easy to do, it has numerous drawbacks: (a) it frequently assumes that the appropriate range of values is identified and that all values are equally likely to occur, (b) the results of the analysis are often reported as a single, most likely value that is considered as perfectly accurate.

- **Scenario analysis.** Scenario analysis is similar to sensitivity analysis except groups of factors are tested to together in a methodical way. Each scenario includes factors that
support a given theme. For example, one scenario could include factors that imply high growth in demand for water and another could include factors that support low growth in demand for water. In this way, scenarios can be compared. This Water Plan uses scenario analysis to consider possible future conditions.

- **Probability analysis.** Although it is recognized that the “true” values of planning and design variables and parameters are not known with certainty and can take on a range of values, it may be possible to describe a variable or parameter in terms of a probability distribution. For example, for a normally distributed variable or parameter, indicators such as mean and variance can be identified which would allow confidence intervals to be placed around point estimates. In other words, instead of saying the benefit/cost (B/C) ratio for a project is 1.20, we might be able to say that we are 90% confident that the B/C ratio exceeds the value of 1.15, which gives the decision-makers more information to consider.

- **Stochastic simulation.** This is also known as Monte Carlo simulation or model sampling. An example of this type of analysis is the Corps’ software program, HEC- FDA (Flood Damage Assessment) that directly incorporates uncertainties into a flood damage analysis. For example, direct inputs into this program include frequency/discharge, stage/discharge and structural inventories for which stage/damage curves are determined within the program. FDA statistically assigns error bands around all of these relationships, and then through a Monte Carlo analysis, samples within the various relationships’ error bands in order to determine expected annual damage. Although this program is still subject to the same fundamental sources of uncertainty (model specification and data collection/measurement), at least it explicitly attempts to incorporate uncertainty into the flood damage analysis.

**Risk Assessment Examples**

As mentioned previously, risk assessments provide a way to quantitatively consider the uncertainties that relate to events of interest. DWR and others are beginning to conduct more risk assessments as part of planning for the future. The Water Plan encourages all resource planners to incorporate risk assessments into their planning for integrated regional water management. The assessments provide the basis for balancing risks with rewards in planning for a sustainable future. Some examples of ongoing risk assessments are shown below.

**Delta Risk Management Strategy.** The Delta Risk Management Strategy (DRMS) is evaluating Delta issues from the perspective of the risks from levee failures and ways to reduce those risks.

DRMS provides a framework for evaluating major threats to the Delta levee system and the impacts that levee failure can have on the Delta ecosystem and economy, the State’s water delivery system and other infrastructure, and those who rely on the exports of fresh water from the Delta. The purpose of DRMS is to:

- Evaluate the risk and consequences to the state (e.g., water export disruption and economic impact) and the Sacramento-San Joaquin Rivers Delta (e.g., levees, infrastructure, and ecosystem) associated with the failure of Delta levees and other assets considering their exposure to all hazards (seismic, flood, subsidence, seepage, sea level rise, etc.) under present as well as foreseeable future conditions. The evaluation assesses the total risk as well as breaking the risk down for individual islands.

- Propose risk criteria for consideration of alternative risk management strategies and for use in management of the Delta and the implementation of risk-informed policies.
• Develop a management strategy, including a prioritized list of actions to reduce and manage the risks of consequences associated with Delta levee failure.

For more information on DRMS, visit the website at http://www.drms.water.ca.gov/.

The DRMS assessment provides preliminary estimates of the probability that multiple islands will flood simultaneously during a 25-year exposure period due to a seismic event as shown in Figure 5-3. The figure shows that there is about a 25 percent chance that 30 islands would fail simultaneously from a seismic event sometime within the next 25 years. DRMS estimated that failures that flood 30 islands could disrupt Delta water exports for 16 to 23 months due to salt intrusion which could reduce water exports by 6.5 million acre-feet to 9.3 million acre-feet.

**PLACEHOLDER Figure 5-3 Probability of a number of simultaneous levee failures from a seismic event during a 25-year exposure period**

**California Statewide Levee Database.** California has over 13,000 miles of levees that protect residential and agricultural lands. The levee failures in New Orleans during hurricane Katrina prompted DWR to initiate development of a state-of-the-art levee database for the purpose of better understanding and managing levees. The California Levee Database (CLD) will support an efficient and effective methodology for assessing levee reliability risk assessment factors and structural data impacting individual levee reaches. The CLD is being coordinated with a similar database being developed by USACE.

**DWR Economic Analysis for Flood Risk Management.** DWR has prepared draft procedures for consistent economic analysis for the large list of flood risk reduction studies and projects that are underway or will be started over the next several years. These include major analyses for the Central Valley Flood Protection Plan, the State Plan of Flood Control, regional flood management planning, and various bond grant programs.

Because of its considerable water management partnerships with the federal government, DWR has a policy that all economic analyses conducted for its internal use on programs and projects be fundamentally consistent with the federal Economics and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G), which was adopted by the U.S. Water Resources Council on March 10, 1983, and is currently being revised for the first time in 25 years. In addition, The USACE requires that “risk analysis” be conducted for all of its flood damage reduction studies. For agencies seeking USACE funding and/or levee certification, it is strongly recommended that “risk analyses” be conducted. USACE guidance on risk analysis can be found in:

- EM 1110-2-1619, Risk-Based Analysis for Flood Damage Reduction Studies, August, 1996
- ER 1105-2-101, Risk Analysis for Flood Damage Reduction Studies, January 2006

**Least-Cost Planning Simulation Model.** DWR developed the Least-Cost Planning Simulation Model (LCPSIM) to evaluate risks of water supply shortages. It is a yearly time-step simulation/optimization model that assesses the economic benefits and costs of enhancing urban water service reliability at the regional level. The LCPSIM output includes the economically efficient level of adoption of reliability enhancement measures by type, including the cost of those measures. The LCPSIM accounts for the ability of shortage event management (contingency) measures, including water transfers, to mitigate regional costs and losses associated with shortage events as well as the ability of long-run demand reduction and supply augmentation.
measures to reduce the frequency, magnitude, and duration of those shortage events. Forgone use is the difference between the quantity demanded and the supply available for use.

**Presenting Uncertainty About Climate Change to Water-Resource Managers.** This report documents a series of three workshops conducted by RAND with the Inland Empire Utilities Agency (IEUA) in southern California in fall 2006. The workshops were supported by modeling to explore how different descriptions of uncertainty about the effects of climate change and other key factors on IEUA’s projected supply and demand might influence water managers’ perceptions of risk and preferences for new infrastructure investments, changes in operational policies, and adoption of regulatory measures. RAND used analysis called Robust Decision Making (RDM), a new approach to decision support when conditions present deep uncertainty. RDM uses computational methods to identify scenarios likeliest to break assumptions embedded in a long-term resource-management plan.

The report presents a decision analysis of potential IEUA-region water-planning responses using three different formulations of uncertainty: traditional scenarios; long-term, probabilistic forecasts; and policy-relevant scenarios. The modeling showed periods of water shortages under different scenarios. As one example, Figure 5-4 shows estimated supply conditions for one scenario.

**Managing for Sustainability**

Over the past few decades, questions have been raised about how sustainable the ecosystem, water use, land use, and other uses are given current management practices and expected future changes. California’s water resources are finite and require more careful management for sustainability of resources than has been practiced during the first 150 years of the state’s history.

**What is Sustainability?**

The word, “sustainability”, has been widely tossed around in recent years for a wide variety of planning activities, and often, no definition is provided with its use. The need for “sustainable development” or “sustainable use of resources” may have somewhat different meanings depending on the perspective of the user. A system or process that is sustainable can generally continue indefinitely. The intent here is not to give a strict definition, but to portray the concepts of longevity and resilience. A system that is sustainable, should meet today’s needs without compromising the ability of future generations to meet their own needs. A sustainable system generally provides for the economy, the ecosystem, and equity.

For this Water Plan, incorporating the concept of resource sustainability into water planning is an ongoing process or approach that will continue to be developed in future water plan updates. The process includes broad principles for planning for sustainability rather than defining a specific desired outcome.

**PLACEHOLDER Box 5-2 Often Quoted Definition of Sustainability**

Since 2002, the Sustainable Water Resources Roundtable (SWRR) has brought together State, federal, corporate, non-profit and academic sectors to advance understanding of the nation’s
water resources and to help develop tools for their sustainability. SWRR concluded that discussions of water sustainability offer the most promise when there is an understanding of major driving forces like population, income, land use, climate change, and energy use. SWRR identified a set of four sustainability principles for water resource management (see Box 5-3 SWR Sustainable Principles).

**PLACEHOLDER Box 5-3 SWRR Sustainability Principles**

**Sustainability Indicators**

SWRR says that, “indicators represent a way to measure progress. They can provide a metric for understanding the extent to which water resources are managed to meet the long term needs of our social, economic and environmental systems. In essence, they can help us understand whether or not the nation is on a sustainable course in its management of water and related resources.” SWRR has developed a set of 14 key sustainability indicators (see Box 5-4) that can be useful to other entities developing their own indicators. A more detailed list of indicators is included in Volume 4 Reference Guide.

**PLACEHOLDER Box 5-4 SWRR Sustainability Indicators**

Sustainability indicators may vary depending on the water agency or region of California. Defining indicators is an ongoing, iterative process for most entities. The CALFED Bay-Delta Program has been working to develop performance measures for water supply reliability, water quality, levee system integrity, and ecosystem restoration since its Record of Decision in 2000. The Water Plan team will develop indicators to accompany the various management actions selected for implementation.

**Examples of Managing for Sustainability**

It is becoming increasingly evident to decision-makers, water managers, and planners of the need to manage for the long-term sustainability of resources. This is especially true in the face of climate change, population growth, and evolving environmental protections.

Water Plan Update 2005 was the first California Water Plan to emphasize integrated regional water management as a key component in managing for sustainability. To ensure that water use is sustainable, California water management must be based on three foundational actions: use water efficiently, protect water quality to get maximum utility from existing supplies, and promote environmental stewardship to manage water in ways that protect and restore the environment. These actions support two initiatives that water management must pursue to ensure reliable water supplies: first, promote and practice; and second, maintain and improve statewide water management systems, the backbone of water management in California.

*To achieve sustainability, water and resource managers and planners must transition from the past model that places value primarily on water supply yield and move to valuing the sustainability of the system (see Box 5-5).* Integrated regional water management relies on a diversified portfolio of water strategies. This diversification is essential to provide the flexibility needed to cope with changing and uncertain future conditions. Sustainable development relies on policies, decisions, and actions that give full consideration to social, economic, and environmental issues.
There are numerous examples of entities planning for sustainability. Many of these are based on integrated regional water management plans, each relying on portfolios of management strategies that fit their specific needs. Following are a few examples of how different entities are approaching the need for sustainability.

**The Water Wiki**
The Sustainable Water Resources Roundtable serves as a forum to share information and perspectives that will promote better decision making in the U.S. regarding the sustainable development of the nation's water resources. The Roundtable began a Web Wiki to support ongoing discussions on sustainability. Readers can view information already on the Wiki and can contribute their own information and ideas for viewing by others. The Water Wiki can be found at [http://mailcenter.comcast.net/wmc/v/wm/48BEC3B30004EDBC0000251D220076139400009D019B9B010DD204?cmd=Show&no=1&uid=51047&sid=c0](http://mailcenter.comcast.net/wmc/v/wm/48BEC3B30004EDBC0000251D220076139400009D019B9B010DD204?cmd=Show&no=1&uid=51047&sid=c0).

**Metropolitan Water District Integrated Water Resources Plan**
Metropolitan adopted its original Integrated Water Resources Plan in 1996. The plan took into account what was known about the water system, factored in changes that could be expected, and planned for uncertainties by including contingencies. The plan called for investments in water conservation, recycling, groundwater treatment, storage, and water transfers. Metropolitan and its member agencies updated the plan in 2004 because they wanted to ensure that the plan would continue to be successful in providing reliability, diversity and flexibility for the region. The agencies are now working on a plan update for 2009. Drought conditions on the Colorado River, deteriorating environmental conditions in the Delta, and climate change are some key issues that will be addressed in this next plan update. The Metropolitan web portal [http://www.mwdh2o.com/index.htm](http://www.mwdh2o.com/index.htm) mentions that a basic strategy is to plan to develop more supplies than predicted to be necessary to provide a buffer to help address unexpected changes to local demand. These periodic updates of the Integrated Water Resources Plan demonstrate that planning for sustainability is a dynamic process to anticipate and keep pace with changing conditions.

**Santa Ana Integrated Watershed Plan**
The Santa Ana Watershed Project Authority developed the Santa Ana Integrated Watershed Plan to integrate storm and flood water management, environment and habitat, water recycling, recreation and conservation, water storage, and groundwater cleanup. The plan calls for investing over $200 million in the watershed. The vision for the completion of all proposed projects in the watershed is a sustainable Santa Ana Watershed that is drought-proofed, salt balanced, and supports economic and environmental vitality in the year 2030. More information on SAWPA and the Santa Ana Integrated Watershed Plan can be found on the web portal [http://www.sawpa.org/](http://www.sawpa.org/) and [http://www.sawpa.org/iwp/#IWP-Update](http://www.sawpa.org/iwp/#IWP-Update).

**Plumas County Integrated Regional Water Management Plan**
The Upper Feather River Integrated Regional Water Management Plan is for a rural area. It includes stream and meadow restoration and erosion control at priority sites in the Plumas National Forest; new wetlands to expand municipal tertiary wastewater treatment; well inventory and capping in Sierra Valley to prevent groundwater contamination; implementing model management practices on two Feather River Land Trust ranches in Sierra and Genesee Valleys;
and a modeling program in Sierra Valley to support integrated land and water management decision making. The projects create 37 acres of constructed wetlands, rewater 1,300 acres of desertified meadow, reduce summer water temperatures, improve wastewater treatment, restore 50 miles of degraded perennial streams, and provide essential data and tools for future management decisions.

**Delta Vision Strategic Plan**

Executive Order S-17-06 launched Delta Vision in early 2007 to manage the Delta “over the long term to restore and maintain identified functions and values that are determined to be important to the environmental quality of the Delta and the economic and social well-being of the people of the state”. The Blue Ribbon Task Force appointed to develop a strategic plan for the Delta concluded that current behaviors and policies for the Delta are unsustainable. The Task Force also concluded that Delta ecosystem and a reliable water supply for California are the primary, co-equal goals for a sustainable Delta. The Task Force developed their vision for the Delta in December 2007 and their strategic plan in October 2008. The Delta Vision Strategic Plan sets forth strategies necessary to meet the state’s needs for environmental stewardship and water supply, and the needs of the Delta itself. More information on the Strategic Plan can be found on Delta Vision web portal (http://deltavision.ca.gov/)

PLACEHOLDER Table 5-1 Goals and strategies for a Sustainable Delta

**Local Government Commission**

The Local Government Commission (LGC) is a nonprofit, nonpartisan, membership organization that provides inspiration, technical assistance, and networking to local elected officials and other dedicated community leaders who are working to create healthy, walkable, and resource-efficient communities. The LGC web portal (http://www.lgc.org/index.html) includes useful information on community planning and principles that form the basis for the LGC’s work on livable, sustainable communities.

**Example 2050 Analysis for this Water Plan**

For this Water Plan, we evaluated different ways of managing water in California depending on different future conditions and different regions of the state. By considering different response packages, or combinations of water management strategies from Volume 2, the analyses helped show what management would provide for sustainability of the resources. The response packages are ways to manage uncertainty and risk at a regional level.

By considering different potential future conditions (scenarios), this Water Plan Update provides a broad assessment of different combinations of resource management strategies (response packages) that could be used to manage for sustainability. These provide a statewide view of potential response package. More detailed work will be required in the future to refine this information based on the differing conditions and opportunities in the various regions. The following subsections summarize the scenarios and show how they were used in estimating future water demands and response packages for meeting those demands.

**Water Plan Baseline Scenario Descriptions**

Before Water Plan Update 2005, water plan updates based planning assumptions on a single likely future. Now, the use of multiple future scenarios provides decision-makers, water
managers, and planners much more information about how different management actions might perform under a range of possible future conditions.

Update 2009 uses three baseline scenarios to demonstrate how scenarios can be used to better understand the implications of future conditions on water management decisions in this water plan update. The scenarios are referred to as baseline because they represent changes that are plausible and could occur without additional management intervention beyond those currently planned. Each scenario affects water demands and supplies differently.

- **Scenario 1 – Current Trends.** For this scenario, recent trends are assumed to continue into the future.
- **Scenario 2 – Active Institutions.** For this scenario, population growth is slower than currently projected by the Department of Finance and active institutions provide for more efficient planning and development that is less resources intensive than current conditions.
- **Scenario 3 – Expansive Growth.** For this scenario, population growth is faster than currently projected by the Department of Finance and that future conditions are more resource intensive than existing conditions.

Each scenario includes assumptions about how different factors, like population or irrigated farmland, would describe its future. These are factors over which the water community has little control. Following are narrative descriptions of the three scenarios including factors of uncertainty that can be used in the modeling analysis.

**Scenario 1 – Current Tends**

**Economic and Financial**

**Population and land use** - In 2050, nearly 60 million people live in California. The state’s metropolitan areas have continued to grow, spreading boundaries and absorbing once-rural areas like the Sierra Nevada foothills.

**Agriculture** - Irrigated crop land has decreased in some areas where urban development and natural resource restoration have increased. Some agricultural lands remain in production with land conservation agreements. Through a combination of advanced agricultural practices (e.g., multi-cropping) and technology, the agriculture industry has been able to increase the intensity of production as it also shifts to higher value permanent crops.

**Institutional and Political**

California continues to face lawsuits on a regular basis to protect water quality and endangered species. In addition the state has been held liable for billions of dollars in damages from a series of flood events. The state legislature has responded to these lawsuits on a case by case basis, which has created a lot of uncertainty for cities and water managers about future regulatory requirements. Management of many groundwater basins continues to be decentralized and/or non-existent.

**Natural Systems**

Global climate change has affected California’s natural systems. Sea level rise has begun to disrupt ecosystems and communities in coastal areas and ongoing tidal wetland restoration. The
biggest impact is in the Delta where levees protect low-lying lands, many which were already below sea level. Air temperatures have increased throughout the state, and precipitation patterns have become more variable. Loss of mountain snowpack is significant, and peak river flows occur earlier in the spring.

Technological

Water and energy are inherently linked, especially in California. Technology has modestly decreased energy use in water treatment and distribution. Water treatment technology allows more cost-effective clean up of groundwater and brackish water. Meanwhile, some advancement in residential appliances and irrigation technology has increased water use efficiency.

Social Practices

**Land use** - Limited and expensive land forces families to look for affordable homes in the state’s interior valleys. Commuters spend more time getting to and from work. Still, Californians have not abandoned the mild-temperature coastal areas. The state’s population growth in these areas has been more than twice that of any other state.

**Water and energy conservation** - Californians have continued to take advantage of existing rebate incentive programs to improve water and energy conservation.

Scenario 2 – Active Institutions

**Economic and Financial**

**Population and land use** - Population growth has slowed substantially relative to Department of Finance forecasts. In 2050, nearly 45 million people live in California. Californians still locate to the Central Valley as well as the coastal counties. However, growth patterns have become more compact. Clustered urban development patterns have reduced the need for conversion of rural lands that currently provide opportunities for open space, habitat restoration, and refuges that harbor protected and endangered species.

**Agriculture** - Compact urban development and economic incentives have slowed the conversion of agricultural land to urban development. Most agricultural land conversion occurs for environmental restoration and flood protection purposes rather than residential development. Today, strong policies are in place to preserve prime agricultural lands.

**Institutional and Political**

Inspired by a series of legal decisions, California’s legislature has enacted several comprehensive programs to protect and improve water quality, protect fish and wildlife, and protect communities from flooding. These new programs include both regulatory controls and economic incentives. Increased institutional cooperation and agreements among groundwater users facilitate more sustainable use of groundwater basins and increase opportunities for conjunctive use.

**Natural Systems**

(Same as Current Trends) Global climate change has affected California’s natural systems. Sea level rise has begun to disrupt ecosystems and communities in coastal areas and ongoing tidal wetland restoration. The biggest impact is in the Delta where levees protect low-lying lands, many which were already below sea level. Air temperatures have increased throughout the state,
and precipitation patterns have become more variable. Loss of mountain snowpack is significant, and peak river flows occur earlier in the spring.

**Technological**

The West Coast was an early adopter of green technology. Fifty years ago, venture capitalists backed innovated technology as the industry realized that there was money to be made in clean energy. Water treatment technology allows more cost-effective clean up of groundwater and brackish water. New advancement in residential appliances and irrigation technology has significantly increased water use efficiency.

**Social Practices**

**Land use** - Compact development patterns have eased commuter travel as families now find work where they live, and more people are using mass transit. For the coastal communities, compact development has made some housing more affordable and lessened impacts on sensitive coastal habitat.

**Water and energy conservation** – Californians have embraced water and energy conservation significantly more than Current Trends by upgrading residential appliances, installing water efficient landscapes, and investing in renewable energy sources even when utility rebates are not available.

**Scenario 3 - Expansive Growth**

**Economic and Financial**

**Population and land use** – California’s population has grown at a faster rate than projected by the Department of Finance. We have 70 million people living here in 2050. To accommodate those growing numbers, California urban areas have spread and moved into areas that were once rural and in areas susceptible to flooding and fire.

**Agriculture** - Irrigated crop land has decreased significantly in some areas where urban development and natural resource restoration have increased. Some agricultural lands remain in production with land conservation agreements. Through a combination of advanced agricultural practices (e.g., multi-cropping) and technology, the agriculture industry has been able to increase the intensity of production as it also shifts to higher value permanent crops.

**Institutional and Political**

(Same as Current Trends) California continues to face lawsuits on a regular basis to protect water quality and endangered species. In addition the state has been held liable for billions of dollars in damages from a series of flood events. The state legislature has responded to these lawsuits on a case by case basis, which has created a lot of uncertainty for cities and water managers about future regulatory requirements. Management of many groundwater basins continues to be decentralized and/or non-existent.

**Natural Systems**

(Same as Current Trends) Global climate change has affected California’s natural systems. Sea level rise has begun to disrupt ecosystems and communities in coastal areas and ongoing tidal wetland restoration. The biggest impact is in the Delta where levees protect low-lying lands,
many which were already below sea level. Air temperatures have increased throughout the state, and precipitation patterns have become more variable. Loss of mountain snowpack is significant, and peak river flows occur earlier in the spring.

**Technological**

(Same as Current Trends) Water and energy are inherently linked, especially in California. Technology has modestly decreased energy use in water treatment and distribution. Water treatment technology allows more cost-effective clean up of groundwater and brackish water. Meanwhile, some advancement in residential appliances and irrigation technology has increased water use efficiency.

**Social Practices**

- **Land use** – Families prefer low density housing and many seek rural residential properties. These development patterns have expanded urban areas away from existing infrastructure. Mass transit usage is the same as under Current Trends, but the annual miles driven has increased as due to farther commute distances.

- **Water and energy conservation** – Californians have continued to take advantage of existing rebate incentive programs to improve water and energy conservation, but at a slower rate than Current Trends.

**Scenario Water Demands**

Quantitative estimates of water demands for each baseline future scenario are necessary to further define the scenarios and prepare information for the modeling work presented in Chapter 6. Future urban water demand was estimated individually for the residential, commercial, industrial, and public sectors. Agricultural water demand was estimated by using projections of the plausible irrigated crop demand presented by each scenario. Environmental water demand for each scenario was assumed to equal water dedicated to the ecosystem in 2005 plus additional scenario-specific amount. A detailed description of the methods used to estimate future water demands for each California region can be found in the Volume 4 Reference Guide article “______.”

Values for the key factors of uncertainty that affect urban demand (population, single family homes, multi family homes, persons per household, commercial employees, and industrial employees) are reported in Table 5-2 for 2005 and 2050 under each of the three baseline scenarios. Figure 5-5 shows how factors are expected to vary over time for each scenario. The 2050 population for the expansive growth scenario is expected to be about 60 percent higher than that for the active institutions scenario.

| PLACEHOLDER Table 5-2 Scenario factors affecting urban water demand |
| PLACEHOLDER Figure 5-5 Change in scenario factors affecting urban water demand between 2005 and 2050 |

Values for the key factors of uncertainty that affect agricultural water demand (irrigated land area, multi-crop area, and individual cropping patterns) are reported in Table 5-3 and Figure 5-6 for 2005 and 2050 under each of the three baseline scenarios. Each of the scenarios shows a decline in irrigated acreage over existing conditions.
An estimate of the total statewide unmet environmental water objectives for each water year from 1998 through 2007 are shown in Figure 5-7. Table 5-4 shows the same information by scenario for nine different watersheds or specific uses. These are only for the major objectives and do not include all environmental objectives in the state.

Table 5-5 shows how climate change is represented within each of the scenarios. Precipitation, temperature, and relative humidity all have an effect on water use.

The statewide combined (or net) change in scenario water demands from year 2005 to 2050 for average water years is shown in Figure 5-8. This represents only the amount that water demands increase or decrease and not the total demands in 2050.

The statewide changes in net water demands by urban, agricultural, and environmental demand for each of the three scenarios is shown in Figure 5-9. Potential changes in statewide water demand patterns are further illustrated by examining the net water demand changes for each hydrologic region as shown in Figure 5-10.

Figure 5-11 shows these estimated regional water demand changes as a percentage change from 2005 to 2050.
Example Scenario Response Packages

A response package is a set of resource management strategies from Volume 2 designed to provide benefits for a given future scenario. The performance of several different response packages can be compared for each scenario to determine the best performing package. Having response packages for multiple future scenarios can help identify management responses that perform well when compared across the array of possible future conditions.

No single response package will work for all of California as each region has its own needs, constraints, and opportunities. Water Plan participants and regional representatives have been working to define response packages for each region. Table 5-6 shows examples of possible resource management strategies that may be part of response packages for each region. As shown in the table, the response packages are likely to vary significantly among the regions. [note to reader: work is continuing on defining the regional response packages and they will change]

PLACEHOLDER Table 5-6 Example response packages by region

Even though response packages, with individual resource management strategies are still under development, estimates of how the response packages will change supply augmentation and demand reduction between years 2005 and 2050 are shown by region in Figure 5-12. [prepare some observations of what the figure shows when it is ready]

PLACEHOLDER Figure 5-12 Changes in supply augmentation and demand reduction for baseline scenarios by region, 2005-2050

The Water Plan team developed scenario response packages for the state as a whole. Figure 5-13 shows how the water management strategies for each scenario response package are expected to change over time. The figure provides estimates for 2005, 2010, 2020, 2030, 2040, and 2050. [prepare some observations of what the figure shows when it is ready]

PLACEHOLDER Figure 5-13 Statewide water supply changes with response packages for baseline scenarios, 2005-2050

Summary

Integrated regional water management, including integrated flood management, is the basis of planning for California’s water future. In planning for this integrated water management, reducing uncertainties and assessing risks to the system are essential for developing a sustainable plan.

The Water Plan is reducing uncertainty by improved modeling and development of analytical tools. DWR and other entities are conducting various risk assessments so risks can be better balanced with the rewards improved management. This water plan update used three different future scenarios and tested different response packages, or combinations of resource management strategies, for each future scenario. These response packages help decision-makers, water managers, and planners develop integrated regional water management plans, including integrated flood management plans that provide for resources sustainability.

[need modeling results to finish summary]
Table 5-1 Goals and Strategies for a Sustainable Delta

| Goal 1. Legally acknowledge the co-equal status of restoring the Delta ecosystem and creating a more reliable water supply for California. |
| Strategy 1.1: Make the co-equal goal the foundation of Delta and water policy making. |
| Goal 2. Recognize and enhance the unique cultural, recreational, and agricultural values of the Delta as an evolving place, an action critical to achieving our co-equal goal. |
| Strategy 2.1: Apply for federal designation of the Delta as a National Heritage Area, and establish a multi-site State Recreation Area in the Delta. |
| Strategy 2.2: Establish market incentives and infrastructure to protect, refocus and enhance the economic and public values of Delta agriculture. |
| Strategy 2.3: Develop a regional economic plan to support increased investment in agriculture, recreation, tourism, and other resilient land uses. |
| Strategy 2.4: Establish a Delta Investment Fund that provides funds for regional economic development and adaptation. |
| Strategy 2.5: Adopt land use policies that enhance the Delta’s unique values, and that are compatible with the public safety, levee, and infrastructure strategies of Goal 6. |
| Goal 3. Restore the Delta ecosystem as the heart of a healthy estuary. |
| Strategy 3.1: Restore a large area of interconnected habitats—on the order of 100,000 acres—within the Delta and its watershed over time. |
| Strategy 3.2: Establish migratory corridors for fish, birds and other animals along selected Delta river channels. |
| Strategy 3.3: Promote viable, diverse populations of native and valued species by reducing risks of fish kills and harm from invasive species. |
| Strategy 3.4: Restore Delta flows and channels to support a healthy Delta estuary. |
| Strategy 3.5: Improve water quality to meet drinking water, agriculture, and ecosystem long term goals. |
| Goal 4. Promote water conservation, efficiency, and sustainable use. |
| Strategy 4.1: Reduce urban, residential, industrial, and agricultural water demand through improved water use efficiency and conservation. |
| Strategy 4.2: Increase reliability through diverse regional water supply portfolios. |
| Goal 5. Build facilities to improve the existing water conveyance system and expand statewide storage, and operate both to achieve the co-equal goal. |
| Strategy 5.1: Expand options for water conveyance, storage and improved reservoir operations. |
| Strategy 5.2: Integrate Central Valley flood management with water supply planning. |
| Goal 6. Reduce risks to people, property, and state interests in the Delta by effective emergency preparedness, appropriate land uses and strategic investments. |
| Strategy 6.1: Achieve levels of emergency protection consistent with federal and state policies. |
Strategy 6.3: Prepare a comprehensive long-term levee investment strategy that matches the level of protection provided by Delta levees and the uses of land and water enabled by those levees.

Goal 7. Establish a new governance structure with the authority, responsibility, accountability, science support and secure funding to achieve these goals.

Strategy 7.1: Create a new California Delta Ecosystem and Water (CDEW) Council as a policy making, planning and oversight body. Create a new Delta Conservancy to implement ecosystem restoration projects, and increase the powers of the existing Delta Protection Commission. Abolish the existing California Bay Delta Authority, transferring needed CALFED programs to the Council.

Strategy 7.2: Create a California Delta Ecosystem and Water Plan to ensure flexibility and consistency among state, federal and local entities.

Strategy 7.3: Finance the activities called for in the California Delta Ecosystem and Water Plan from multiple sources.

Table 5-2 Scenario factors affecting urban water demand
--the table will be similar to Table 4-2 of the CWPU 2005, but for years 2005 and 2050--

Table 5-3 Scenario factors affecting agricultural water demand
--the table will be similar to Table 4-3 of the CWPU 2005, but for years 2005 and 2050--

Table 5-4 Unmet environmental water objectives by watershed and scenario
--the table will be similar to Table 4-4 of the CWPU 2005, but will include high medium and low values for the three scenarios--

Table 5-5 Climate change factors by scenario
--the table will be will show precipitation, temperature, and relative humidity for the three scenarios--
Table 5-6 Example response packages by region

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Legend

○ Primary resource management strategies included in the response package for the region
○ Other resource management strategies included in the response package for the region

Mockup for Example only - Dot placement will change with analysis
Figure 5-1. Sources of future change and uncertainty
(develop as a two page graphic?)

Sources of Gradual Change and Uncertainty

- **Urban Land Use (population).** Projecting future changes in population, changes in runoff and infiltration with increased impervious area, and changes in water quality impacts becomes more uncertain with the time frame of the projection.

- **Agricultural Use.** Agricultural water use is influenced by land conversions to urban or ecosystem uses, but also depends on cropping patterns driven by water availability and the world economy.

- **Other Land Use.** Conversions of land to ecosystem or other uses can change water use, water quality, ecosystem health, and many other factors. Some ecosystem uses consume more water per acre than agricultural and urban uses.

- **Global Climate Change.** The changing climate presents many uncertainties in the magnitude, pattern, and the rate of potential change:
  - **Snowpack.** California’s snowpack, a major part of annual water storage, is decreasing with increasing winter temperatures.
  - **Hydrologic Pattern.** Warmer temperatures and decreasing snowpack cause more winter runoff and less spring/summer runoff.
  - **Rainfall Intensity.** Regional precipitation changes to climate change remain difficult to determine, but larger precipitation events could be expected with warmer temperatures in some regions.
  - **Sea Level Rise.** Sea level rise is increasing the threat of coastal flooding, salt water intrusion, and even disruption of Delta water exports should levees fail on key islands and tracts.
  - **Water Demand.** Plant evapotranspiration increases with increased temperature.
  - **Aquatic Life.** Higher water temperatures are expected to have a negative affect on some species and may benefit species that compete with native species.
  - **Carbon “Footprint.”** ???

“To stave off water crises in an age of climate change, humans are going to have to manage water, energy and ecosystems together in a system, undeveloped as yet, that takes into account their complex interconnection.” -- Peter Friederici, The Next Market Crunch: Water, July 2008 --

Sources of Sudden or Short-term Change and Uncertainty

- **Delta Vulnerabilities.** The Sacramento-San Joaquin River Delta is highly susceptible to flooding and to disruption of major water supply to the southern portion of the state.

- **Droughts.** The severity, timing, and frequency of future droughts are uncertain.

- **Floods.** The severity, timing, and frequency of future floods are uncertain.

- **Earthquakes.** Even though more is know about earthquakes, their location, timing, magnitudes can cause various effect on water systems.

- **Facility Malfunction.** Deferred maintenance and aging infrastructure can cause unexpected outages in portions of the system.

- **Chemical Spills.** Chemical spills are unpredictable, but can cause disruption of surface and groundwater supplies.

- **Intentional Disruption.** Vandalism, terrorist acts, and even cyber threats pose serious potential impacts to the operational capability of water delivery and treatment systems.

- **Fire.** Wildfire in local watersheds can change the runoff characteristics and water quality for decades.

- **Changing Policies/Regulations/Laws/Social Attitudes.** Some changes in policies, regulations, laws, and social attitudes may be gradual, but some may be sudden:
  - **Relationships between Water Operations and Environmental Impacts.** Rarely is there necessary scientific information on species or the ecosystem as a whole to identify the relationship between water deliveries and the ecosystem or to identify an exact course of action that will restore natural communities and processes.
- **Plumbing Codes.** Future changes in plumbing codes, like the one for installing ultralow flush toilets, could allow use of innovative water fixtures to conserve water.
- **Emerging Contaminants.** The nature and impact of contaminants may be changing in the future, especially as new health risk information is obtained.

**Figure 5-2 Understanding Flood Risks**

Understanding Flood Risks

Flood risk reflects both the probability of flooding and the consequences that would result from flooding. Flood risk can be calculated as:

\[
(\text{Probability}) \times (\text{Consequence}) = \text{Flood Risk}
\]

For example, if an agricultural area has an annual 1 in 50 chance of flooding causing $10 million worth of damage, the annual flood risk for this area would be:

\[
\frac{1}{50} \times 10 \text{ million} = 200,000 \text{ per year}
\]

If levees are improved so that the area has an annual 1 in 100 chance of flooding, the risk is cut in half:

\[
\frac{1}{100} \times 10 \text{ million} = 100,000 \text{ per year}
\]

However, if the area begins to be urbanized and new homes, businesses, and infrastructure are added, the damages or consequences resulting from flooding become much greater. If the consequences of flooding rise from $10 million to $100 million, the flood risk is greatly increased:

\[
\frac{1}{100} \times 100 \text{ million} = 1,000,000 \text{ per year}
\]

So, even when the level of flood protection goes up, the risk may be higher if more people and infrastructure are located in the floodplain. For heavily urbanized areas in deep floodplains, the annual risk is commonly in the billions of dollars.

As we saw in New Orleans after Hurricane Katrina, there is also a huge potential for loss of life and countless personal tragedies when we urbanize in deep floodplains. Such losses are difficult to measure in economic terms, but cannot be overlooked. California is working to reduce flood risk in existing urbanized areas and avoid putting people at risk in areas that do not have adequate flood protection.
Figure 5-3 Probability of a number of simultaneous levee failures from a seismic event during a 25-year exposure period

Figure 5-4 Delivered Supply, Surplus, and Shortages for the Hotter and Drier, Miss Goals Scenario under the 2005 IEUA Urban Water Management Plan
Figure 5-5 Change in scenario factors affecting urban water demand between 2005 and 2050
Figure 5-6 Irrigated crop area by scenario

2050 California Irrigated Crop Area by Scenario

- Multicropped Area
- Irrigated Land Area

Figure 5-7 Unmet environmental water objectives

Summary of Unmet Environmental Objectives
California (not exhaustive)

Figure 5-8 Net changes statewide in average-year water demand for baseline scenarios, 2005 – 2050
--similar to Figure 4-2 of CWPU 2005, except for years 2005-2050--

Figure 5-9 Net changes statewide in average-year water demand for baseline scenarios by sector, 2005-2050
--similar to Figure 4-3 of CWPU 2005, except for years 2005-2050--

Figure 5-10 Net changes in average-year water demand for baseline scenarios by region, 2005-2050
--similar to Figure 4-4 of CWPU 2005, except for years 2005-2050--

Figure 5-11 Percent change in average-year water demand for baseline scenarios by region, 2005-2050
--similar to Figure 4-5 of CWPU 2005, except for years 2005-2050--

Figure 5-12 Changes in supply augmentation and demand reduction for baseline scenarios by region, 2005-2050
--similar to CWPU Figure 4-4, but shows supply augmentation and demand reduction for each region. The bar graphs on the CA map for each region are expected 2005 starting data and then 2050 data for each scenario. Expect each region graphs to have formats similar to following--
Figure 5-13 Statewide water supply changes with response packages for baseline scenarios, 2005-2050

--expect one page with a set of bar graphs for each of the three scenarios. Each scenario will have stacked bar graphs for the major water management strategies for year 2005, 2010, 2020, 2030, 2040, and 2050; expect each set to look similar to example below, but with more management strategies---

Box 5-1 Uncertainty, Risk, and Sustainability

Uncertainty. Uncertainty is what we don’t know about the system. For example, engineers don’t know the foundation conditions under all California levees. Uncertainty can be reduced by reducing data gaps to increase knowledge.

Risk. Most risks originate from hazards like floods, earthquakes, and droughts that would still occur even if all uncertainty could be removed. We want to reduce uncertainty so we have a clearer view of what the risks to the system are.

Risk = probability of the occurrence X consequences of the occurrence

Sustainability. A system or process that is sustainable has longevity and resilience. A sustainable system manages risk, but cannot eliminate risk. A sustainable system generally provides for the economy, the ecosystem and equity. For Update 2009, sustainability is not a specific desired result, but is more of an approach or way of seeking longevity and resilience that will continue to be developed in future water plans. For example, planning ways to eventually eliminate drafting more groundwater than can recharged over the long-term is one approach for improving sustainability.

Box 5-2 Often Quoted Definition of Sustainability

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

The World Commission on Environment and Development, 1987
Box 5-3 SWRR Sustainability Principles

Discussions of water sustainability offer most promise when they take place with an understanding of major driving forces like population, income, land use, climate change, and energy use. To help it navigate within such a context, SWRR identified a set of four sustainability principles for water resources management:

1. **The value and limits of water.** Water supports all life and provides great value. While water is abundant, people need to understand and appreciate that it is limited in many regions, that there are environmental and economic costs of depleting or damaging water resources, and that unsustainable water and land use practices pose serious risks to people and ecosystems. A renewable natural resource is sustainable only if the rate of use does not exceed the rate of natural renewal.

2. **Shared responsibility.** Water does not respect political boundaries. Sustainable management of water requires consideration of the needs of people and ecosystems up- and down-stream and throughout the hydrologic cycle, and avoiding extreme situations that may deplete water in some regions to provide supplies elsewhere.

3. **Equitable access.** Sustainability suggests fair and equitable access to water, water dependent resources, and related infrastructure. Equitable access requires continuous monitoring to detect and address problems as they occur, and means to correct the problems.

4. **Stewardship.** Meeting today’s water needs sustainably challenges us to continually address the implications of our water resources decisions on future generations and the ecosystems upon which they will rely. We must be prepared to correct policies and decisions if they create adverse unintended consequences.

The Sustainable Water Resources Roundtable, SWRR, November 2007

Box 5-4 SWRR Sustainability Indicators

A. **Water availability.** People and ecosystems need sufficient quantities of water to support the benefits, services and functions they provide. These indicator categories refer to the total amount of water available to be allocated for human and ecosystem uses.

   1. **Renewable water resources:** Measures of the amount of water provided over time by precipitation in a region and surface and groundwater flowing into the region from precipitation elsewhere. USGS considers renewable water resources to be the upper limit of water consumption that can occur in a region on a sustained basis.

   2. **Water in the environment:** Measures of the amount of water remaining in the environment after withdrawals for human use.

   3. **Water use sustainability:** Measures of the degree to which water use meets current needs while protecting ecosystems and the interests of future generations. This could include the ratio of water withdrawn to renewable supply.

B. **Water quality.** People and ecosystems need water of sufficient quality to support the benefits, services and functions they provide. This indicator category is for composite measures of the suitability of water quality for human and ecosystem uses.
4. **Quality of water for human uses**: Measures of the quality of water used for drinking, recreation, industry and agriculture.

5. **Quality of water in the environment**: Measures of the quality of water supporting flora and fauna and related ecosystem processes.

6. **Water quality sustainability**: Composite measures of the degree to which water quality satisfies human and ecosystem needs.

**C. Human uses and health.** People benefit from the use of water and water-dependent resources, and their health may be affected by environmental conditions.

7. **Withdrawal and use of water**: Measures of the amount of water withdrawn from the environment and the uses to which it is put.

8. **Human uses of water in the environment**: Measures of the extent to which people use water resources for waste assimilation, transportation and recreation.

9. **Water-dependent resource use**: Measures of the extent to which people use resources like fish and shellfish that depend on water resources.

10. **Human health**: Measures of the extent to which human health may be affected by the use of water and related resources.

**D. Environmental health.** People use land, water and water-dependent resources in ways that affect the conditions of ecosystems.

11. **Indices of biological condition**: Measures of the health of ecosystems.

12. **Amounts and quality of living resources**: Measures of the productivity of ecosystems.

**E. Infrastructure and institutions.** The infrastructure and institutions communities build enable the sustainable use of land, water and water-dependent resources.

13. **Capacity and reliability of infrastructure**: Measures of the capacity and reliability of infrastructure to meet human and ecosystem needs.

14. **Efficacy of institutions**: Measures of the efficacy of legal and institutional frameworks in managing water and related resources sustainably.

*The Sustainable Water Resources Roundtable, SWRR, November 2007*

**Box 5-5 Place Value on Sustainability**

“Because environmental considerations were secondary at best in the middle of the 20th century, the backbone system we operate today is characterized by very high – and unnecessary – levels of conflict between economic and environmental objectives. The clash between these values in recent years has resulted in political and legal conflict, gridlock, and mutual deterioration in the state of both the economy and the environment.”
The central policy goal today, as the Delta Vision recognizes, is to reduce this conflict by investing in a sustainable system. The standard of value in the past for the water industry has generally been the creation of more supply to justify an infrastructure or water management investment. That standard must yield in the future to reflect the enormous value of a sustainable system – one that can provide reliable supplies and a recovering environment far into the future. Similarly, some interests advocate reduced supply as an appropriate measure of value. Both perspectives are off-base. The real prize today is a sustainable system. This may or may not result in increased water supply. The point is that a sustainable system by itself justifies billions in expenditures.”

*Timothy Quinn, Executive Director Association of California Water Agencies, Financing the Delta Vision, April 2008*