Global Climate Changes and its Potential Impact on Zone 7's Water Supply Reliability

Prepared for

Zone 7 Water Agency

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

OVERVIEW

A variety of studies by numerous worldwide organizations, including extensive analysis of decades of data, indicate that the Earth is undergoing significant temperature increases. Many scientists fear that the increased concentrations of greenhouse gases have prevented additional thermal radiation from leaving the Earth, have enhanced the heat-trapping capability of the earth's atmosphere, and are believed to be the cause of global warming. A great deal of climate research, coupled with extensive data gathering and analysis, has lead to development of sophisticated climate models by leading governmental and academic researchers. On the whole, these models indicate that climate change is forecasted to continue and in some cases accelerate. This could have enormous implications over time to water resources management.

PURPOSE

The purpose of this report is to provide the Zone 7 Water Agency (Zone 7) with a summary and evaluation of available information regarding the following issues:

- An overview of global climate change (including its potential impacts to global, national and local resources),
- Its potential impacts on the Sacramento-San Joaquin Delta (including water supply availability and reliability, water quality, flood control and other aspects),
- Its potential impacts on Zone 7's water supply reliability and other operations, and
- Potential water management options to address future climate change and its impacts.

OVERVIEW OF GLOBAL WARMING AND CLIMATE CHANGE

During the last ice age, the atmosphere's carbon dioxide (CO_2) concentration was just 180 parts per million (ppm). After the glaciers retreated, but before the dawn of the modern era, the CO_2 concentration level increased to a comfortable 280 ppm[1]. What has many people worried is that over the past 250 years humans have been artificially increasing the concentration of greenhouse gases (carbon dioxide, methane, nitrogen oxide and chlorofluorocarbons) in the atmosphere. Since the beginning of the industrial revolution, human activities have been adding measurably to natural background levels of greenhouse gases. In just the past century and a half, we have pushed the level of atmospheric carbon dioxide to 381 ppm[2]. Many scientists fear that the increased concentrations of greenhouse gases have prevented additional thermal radiation from leaving the Earth, have enhanced the heat-trapping capability of the earth's atmosphere, and are believed to be the cause of global warming and climate change.

Scientific research has indicated for more than a decade that global warming and regional/global changes to our climate are underway. Technical journals have published peer-reviewed articles on climate change for many years. In August 2005, the Journal of the American Water Works

Association published an article putting climate change into a water resources manager's perspective. Many of the technical studies have come to the attention of the federal and State governments.

In June 2005, Governor Schwarzenegger issued Executive Order S-3-05 recognizing the importance of climate change impacts to California, and calling for assessments of climate change impacts and development of mitigation and/or adaptation plans. In December 2005, in response to the Governor's executive order, the California Energy Commission released a draft report, "Climate Warming and Water Supply Management in California." The Public Policy Institute of California conducted a survey, "Special Survey on the Environment", reporting in July 2005 that 86 percent of the California public believes that global warming will affect current or future generations. 2005 was a breakthrough year in wide recognition of the reality of climate change and its potential impacts to Californians.

There are three major indicators of climate change. They include:

- Temperature,
- Receding glaciers, and
- Sea level rise.

Temperature

Global mean surface temperatures have increased 0.6 to 1.2°F since the late 19th century, and the fifteen warmest years in the 20th century have all occurred since 1980, and the 1990s were the warmest decade of the entire millennium. In June 2006, the National Academy of Sciences reported that the "recent warmth is unprecedented for at least the last 400 years and potentially the last several millennia."

Receding Glaciers

Since 1950, the Antarctic Peninsula has warmed by 4°F, four times the global average increase. Since 1995, more than 5,400 square miles, an area equal to Connecticut and Rhode Island combined, have broken off the Antarctic ice shelves and melted. In 2002, a Rhode Island-sized section of the Larsen B ice shelf, which sits offshore of the Antarctic Peninsula, disintegrated in only 35 days. In 2003, the Ward Hunt Ice Shelf, the largest in the Arctic, broke in two. Overall, since the 1950's, the surface area of the Arctic's sea ice has shrunk by 10 to 15 percent in spring and summer, and the ice has thinned by about 40 percent in late summer and early autumn.

Sea Level Rise

Worldwide measurements of sea level show a rise of 0.1 to 0.2 meters (4 to 8 inches) over the last century, ten times the average rate over the past 3,000 years (0.4 to 0.8 inches; about ½ to ¾ of an inch). Sea level measurements collected at Fort Point in San Francisco since before 1900, from the longest continuous sea level record for any site on the west coast of North America, indicate an approximate 8-inch increase in average sea level since 1900.

EVIDENCE OF CLIMATE CHANGE IN CALIFORNIA

In California and throughout western North America, signs of a changing climate are evident. During the last 50 years, winter and spring temperatures have been warmer, spring snow levels in lower- and mid-elevation mountains have dropped, snowpack has been melting one to four weeks earlier, and flowers are blooming one to two weeks earlier.

There are also a number of large-scale changes that we have seen in the West in the past few decades that may be an indication of climate change. For example, the California drought during the period 1987-1994 was the first prolonged drought since the 1930s. The continuing "west-wide" drought on the Colorado River is unprecedented in recorded history. And, a number of years ago, Department of Water Resources Chief Hydrologist Maurice Roos, began evaluating the April-July snowmelt runoff from the Sierra Nevada. He concluded that there appeared to be a long-term declining trend that could have profound implications to water resources management in California.

In California, 2005 was very wet year, and these conditions continued into 2006. Major storms led to record precipitation and snowfall in January 2005. In December 2005 and January 2006, the largest rainfall totals since 1997 occurred in many parts of northern California and led to damaging floods and mudslides.

THE DELTA AND POTENTIAL IMPACTS OF CLIMATE CHANGE

The Sacramento-San Joaquin Delta is a unique and valuable resource and an integral part of California's water system. It receives runoff from over 40 percent of the State's land area including flows from the Sacramento, San Joaquin, Mokelumne, Cosumnes, and Calaveras rivers. The Delta provides habitat for over 750 species of fish, birds, mammals, and plants; supports agricultural and recreational activities; and is the focal point for water distribution throughout the State.

As the hub of California's two largest water distribution systems, the Bureau of Reclamation's Central Valley Project (CVP) and California's State Water Project (SWP), the Delta is critical to the national economy because it protects and channels the drinking water for two-thirds of the state (for more than 23 million people) and irrigation water for over 7 million acres of some of the most highly productive agricultural land in the world.

The CVP and the SWP are each operated under strict guidelines, with constraints that have to be met prior to water being available for export. Flood control storage in reservoirs, water rights in upper Sacramento and San Joaquin, minimum flow requirements in the rivers and the Delta, dissolved oxygen concentration in the Stanislaus River, 800,000 acre-feet per year reserved for restoration of fish, wildlife and habitat restoration and salinity standards in the Delta are all critical factors used in determining actual pumping operations. Even under existing supply and demand patterns, water requirements are barely met under dry and critical water years. Therefore, climate change and its resultant impacts to snowpack, runoff, and flood control, and the increase in extreme weather conditions (both wet and dry), must be considered in determining future reservoir, and water supply planning and operations.

The following provides a summary of the potential impacts of climate change to water supply operations in the Delta, as they relate to water supply reliability, water quality and flood control.

Water Supply Reliability

- The operation of storage reservoirs could be impacted by shifting runoff and snowmelt patterns, requiring more need for flood control storage, and making it more difficult to refill reservoir flood control space during late spring or early summer and potentially reducing the amount of surface water available for use during the summer/fall season.
- Levee breaks, either as a result of the impacts of rising sea levels, lack of maintenance, earthquake, or some combination, could have adverse affects on Delta water quality (due to the intrusion of salt water into these potable water supplies) and water system operations. Major levee breaks could take months or years to repair, and will impact the availability of water supplies from the Delta.

Water Quality

- More intense storms and increased runoff could impact Delta water quality in two ways:
  1. Increased sediment load, and
  2. Increased contaminants from increased urban and agricultural runoff.
- Sea level rise could push salt water from the Bay into the Delta impacting overall water quality and potentially impacting Delta operations.
- Levee breaks, either as a result of the impacts of climate change or an earthquake, could cause large amounts of salt water from the Bay to enter the Delta and would have adverse affects on Delta water quality and water system operations. The saltwater intrusion could take months to dissipate depending on the severity of the levee break and the amount of saltwater intrusion which occurs.

Flood Control

- Reservoir operations, including the need for more flood storage reservoir space, could be impacted by snowpack changes, shifts in snowmelt patterns and changes in rainfall intensity.
- Deteriorating levees could fail as a result of increased runoff, more intense storms, sea level rise, or lack of maintenance. Failure of the levees would have catastrophic impacts on the Delta, including its islands and have huge impacts on water supply operations.

As discussed in this report, climate change could lead to higher snow levels and less snowpack, which would lead to less spring runoff. At the September 2005 conference "Urban Water Supplies and Climate Change in the West," DWR Director Lester Snow stated the following: "A 3°C (5.4°F) rise in temperature over the next century (a 'moderate' projection) is expected to increase the snow elevation by about 1,500 feet. This could result in a loss of water storage in the Sierra snow pack on the order of 4 to 5 million acre-feet." To put this into further perspective, the potential snow pack storage loss is equivalent to the 4.5 million acre-feet storage capacity of Shasta Reservoir.

A recent report completed by the California Department of Water Resources (DWR) in July 2006 describes some of the potential climate change impacts on the SWP and CVP:

- In three of the four climate change scenarios simulated, there were significant shortages in water supply availability from CVP north-of-Delta reservoirs during droughts.
- Changes in annual average SWP south-of-Delta Table A deliveries ranged from a slight increase of about 1 percent for a wetter scenario to about a 10 percent reduction for one of the drier climate change scenarios. Increased winter runoff and lower Table A allocations resulted in slightly higher annual average Article 21[i] deliveries in the three drier climate change scenarios. However, the increases in Article 21 did not offset losses to Table A. The wetter scenario with higher Table A allocations resulted in fewer Article 21 delivery opportunities and slightly lower annual average Article 21 deliveries.
- Changes in annual average CVP south-of-Delta deliveries ranged from increases of about 2.5 percent for a wetter scenario and decreases of as much as 10 percent for drier climate change scenarios.
- For both the SWP and CVP, carryover storage was negatively impacted in the drier climate change scenarios, and somewhat increased in the wetter climate change scenario, if reservoir storage were available to take advantage of these opportunities.
- At present sea level, there is flexibility within the system to modify existing reservoir operations and Delta exports to be able to account for potential climate change scenarios, and still comply with chloride standards at municipal and industrial intakes.
- A one-foot rise in sea level, without any changes to the system operations, delivered chloride concentrations would increase, and be above the 250 mg/L threshold 10 percent of the time at Old River at Rock Slough. These effects could probably be mitigated with operational adjustments (i.e., release more water to further reduce the chloride concentration), which would likely translate into a reduced water supply available to the SWP and CVP contractors.
- With a one-foot rise in sea level, maintaining chloride concentrations below the 150 mg/L threshold would be even more challenging during critical and dry years, likely requiring dedication of additional water supplies to repulse sea water, in order to maintain Delta water quality conditions.

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[i] Article 21 water is additional SWP water sometimes available to certain SWP contractors after SWP Table A water deliveries are met.

POTENTIAL FOR LEVEE FAILURE AND IMPACTS TO THE SWP AND CVP

The aging Delta levee system is currently subject to risks from high inflows during storm events, high tides (particularly during high flow events), high winds, low capacity of adjacent channels due to sedimentation, earthquakes, wind waves and erosion, waves generated by boat and ship traffic, subsidence, under seepage, burrowing animals, sea level rise, and inadequate maintenance practices and funding.

Because of the vast area of the Delta and its infrastructure, its vulnerability to an earthquake is higher than that of an individual structure. Shortly after Hurricane Katrina, Lester Snow, Director of DWR, outlined what could happen to California in the event of a 6.5-magnitude earthquake occurring on a fault in the West Delta.

- At the time of the quake, Delta levees would break in about 30 places on 16 islands, flooding homes and farmland.
- 200 miles of levees will be weakened by slumping, cracking and increased seepage; without repairs, these damages will lead to additional levee failures.
- Due to the damaged levees, saltwater from San Francisco Bay is drawn into the Delta (an estimated 300 billion gallons in the first few days), forcing the SWP and the CVP to shut down and cutting off water delivery to much of the Bay Area, Central California and Southern California.
- Levee damage causes failure of the Mokelumne Aqueduct.
- The flooding damages major power and gas transmission lines, affecting power delivery to the entire state.
- Up to 3,000 homes are inundated.
- 85,000 acres of agricultural land and crops are flooded.
- State Highways 4, 12 and 160 are inundated and railroads are damaged.
- Much of the Delta ecosystem is devastated; it takes at least 15 months to repair the Delta, and the economic impact to the State is about $30 to 40 billion over a five-year period.

POTENTIAL IMPACTS TO ZONE 7'S WATER SUPPLY RELIABILITY

Zone 7's water supply reliability planning is currently based on a SWP average annual yield of approximately 75.6 percent of Zone 7's Table A entitlement (80,619 acre-feet per year, afa), or 60,900 afa, once all SWP Contractors are requesting their full entitlements.

Recently, DWR has updated its SWP delivery reliabilities using the CalSim II computer simulation model for existing and future levels of development in the water source areas, assuming historical patterns of precipitation. This updated data was presented in DWR's April 2006 report entitled "The State Water Project Delivery Reliability Report 2005." Zone 7's anticipated delivery under the updated delivery reliabilities based on Zone 7's current Table A entitlement of 80,619 afa is 77 percent (62,077 afa) in 2025. The 2025 delivery of 77 percent is about 1.5 percent higher than the 75.6 percent long-term average SWP delivery currently assumed by Zone 7. However, it should be noted that the updated SWP reliabilities are based on historical hydrology and precipitation data and do not account for future uncertainties such as changes in the climate pattern or levee failure in the Delta due to flooding or an earthquake.

DWR has begun evaluating the potential impacts of climate change on SWP delivery reliability. Based on climate change scenarios evaluated to date, changes in annual average SWP Table A deliveries ranged from an increase of about 1 percent for a wetter scenario to about a 10 percent reduction for one of the drier climate change scenarios. Assuming a 10 percent reduction in delivery reliability due to climate change, and based on the revised delivery reliabilities discussed above, Zone 7's 2025 average delivery would be reduced from 77 percent to about 69 percent (55,869 afa). This average year delivery is significantly lower than the long-term average SWP delivery currently assumed by Zone 7 (75.57 percent, or 60,948 afa).

If a major earthquake were to occur in the vicinity of the Delta, the SWP could be shut down for months or even years due to levee failure and saltwater intrusion. Under such a scenario, Zone 7's supply from the SWP would be unavailable, and Zone 7 would need to rely entirely on its local surface water (Lake del Valle) and groundwater supplies until the SWP system could be restored. As discussed, in Section 3, it could take 15 months or longer to repair the Delta after a major earthquake.

POTENTIAL IMPACTS TO OTHER ZONE 7 OPERATIONS

Climate change may also impact Zone 7's other operations. Specifically, with respect to groundwater management, the Salt Management Plan, groundwater recharge operations and Chain-of-Lakes operations may be impacted by changes in precipitation patterns and intensities. Similarly, operation of Lake Del Valle could be impacted by the need to maintain more flood control storage capacity to deal with more intense rainfall events. Lastly, flood control operations in general may be impacted by more intense and more frequent flooding events.

POTENTIAL MANAGEMENT STRATEGIES TO ADDRESS CLIMATE CHANGE

Irrespective of cause or possible severity, climate change is here and water resource managers need to plan for potential impacts as part of their future programs. Impacts to water supply reliability are specific to individual water systems, since some are more directly dependent on annual climate conditions than others. Climate change also needs to be taken in context with other uncertainties faced by water resource managers, including the uncertainty of future population increases and the associated potable water demand increase within their service areas.

According to DWR, while numerous water resource management options exist, the following recommendations make sense for most California water utilities:

- Consider re-regulation of surface water reservoirs (potentially re-designating a portion of the available storage for flood control storage space),

- Diversify supplies as much as possible, especially in the areas of water transfers, groundwater banking, and conjunctive use, and
- Increase the efficient use of all supplies through conservation and reuse.

For water agencies, like Zone 7, that are very reliant on Delta supplies, the following actions should be considered to be better prepared in the event of a possible catastrophic failure of the Delta:

1. Adopt a policy statement that recognizes the importance of the Delta (from both a water quantity and water quality standpoint), to the Zone's Integrated Water Resources Plan, and continue to work with other agencies to develop and implement a solution,
2. Continue to evaluate and develop additional local storage opportunities,
3. Continue to explore and develop emergency supply plans with other adjacent water agencies, and
4. Apply for additional local water rights to allow for diversion and use of local watershed runoff during high flow periods.

With respect to Item 1 above, in July 2006, Zone 7 adopted a resolution adopting several policy principles for the preservation of a healthy Bay-Delta ecosystem that continues to support water quality and reliability needs in the State of California.

SECTION 1. INTRODUCTION

OVERVIEW

A variety of studies by numerous worldwide organizations, including extensive analysis of decades of data, indicate that the Earth is undergoing significant temperature increases. Many scientists fear that the increased concentrations of greenhouse gases have prevented additional thermal radiation from leaving the Earth, have enhanced the heat-trapping capability of the earth's atmosphere, and are believed to be the cause of global warming. A great deal of climate research, coupled with extensive data gathering and analysis, has lead to development of sophisticated climate models by leading governmental and academic researchers. On the whole, these models indicate that climate change is forecasted to continue and in some cases accelerate. This could have enormous implications over time to water resources management.

REPORT PURPOSE

The Zone 7 Water Agency (Zone 7) is a water wholesaler which provides treated water supplies for over 175,000 people in Alameda and Contra Costa counties. On the average, 75 percent of Zone 7's water comes from the Delta; the rest comes from local surface water and groundwater supplies. Zone 7's Delta water supplies, conveyed to Zone 7 via the State Water Project's (SWP) South Bay Aqueduct (SBA), are subject to numerous constraints, including but not limited to SWP operations and facilities constraints, hydrologic conditions, water quality constraints, and environmental restrictions. In the future, the availability, reliability and management of these Delta water supplies will be impacted by climate change.

Zone 7 has acknowledged the potential impacts of climate change on its Delta water supply reliability and, in early 2006, requested West Yost Associates (WYA) to prepare this report to provide a summary and evaluation of available information regarding the following issues:

- An overview of global climate change (including its potential impacts to global, national and local resources),
- Its potential impacts on the Sacramento-San Joaquin Delta (including water supply availability and reliability, water quality, flood control and other aspects),
- Its potential impacts on Zone 7's water supply reliability and other operations, and
- Potential water management options to address future climate change and its impacts.

REPORT ORGANIZATION

This report is organized into the following sections:

- Section 1: Introduction
- Section 2: Overview of Global Climate Change
- Section 3: Potential Climate Change Impacts to the Delta
- Section 4: Potential Impacts to Zone 7 Water Supply Reliability
- Section 5: Potential Impacts to Other Zone 7 Operations
- Section 6: Water Management Options to Address Climate Change and Its Impacts

SECTION 2. OVERVIEW OF GLOBAL CLIMATE CHANGE

GLOBAL WARMING VS. GLOBAL CLIMATE CHANGE

The phrases "global warming" and "global climate change" are often used interchangeably in the media. Regardless of the causes of global warming, impacts on climate vary by region. While many areas have seen regional temperature increases, other regions are experiencing long-term temperature decreases. Due to these phenomena, many scientists prefer to use "global climate change" since it is more descriptive of the factors that contribute to changes that affect human needs and the environment.

WHAT IS GLOBAL WARMING?

Overview of the Greenhouse Effect

Energy from the sun drives the earth's weather and climate. Absorption of solar energy heats up our planet's surface and atmosphere and makes life on Earth possible. However, the energy does not stay bound up in the Earth's environment forever. If it did, then the Earth would grow hotter and hotter until its temperature exceeded that of the sun.

Instead, as the rocks, the air and the sea heat, they emit thermal radiation. Much of this thermal radiation, which is largely in the form of long-wave infrared energy, travels directly out into space, leaving the Earth and allowing it to cool. Some of this outgoing long-wave infrared radiation, however, is re-absorbed by water vapor, carbon dioxide, and other greenhouse gases in the atmosphere (including methane, nitrogen oxide and chlorofluorocarbons). These gases then absorb and "trap" this energy, and re-radiate it back toward the Earth's surface, creating a natural "greenhouse effect". This greenhouse effect is a good thing, and is the reason that the Earth's average surface temperature is the comfortable 15°C (59°F) that it is today[3]. If there were no greenhouse gases or clouds in the atmosphere, the Earth's average surface temperature would be a very chilly -18°C (-0.4°F). Figure 2-1 shows a graphic representation of the greenhouse effect.

Artificial Increase of Greenhouse Gases

During the last ice age, the atmosphere's carbon dioxide (CO_2) concentration was just 180 parts per million (ppm). After the glaciers retreated, but before the dawn of the modern era, the CO_2 concentration level increased to a comfortable 280 ppm[4]. What has many people worried is that over the past 250 years humans have been artificially increasing the concentration of greenhouse gases (carbon dioxide, methane, nitrogen oxide and chlorofluorocarbons) in the atmosphere. Since the beginning of the industrial revolution, human activities have been adding measurably to natural background levels of greenhouse gases. In just the past century and a half, we have pushed the level of atmospheric carbon dioxide to 381 ppm[5].

The burning of fossil fuels (coal, oil and natural gas) for energy is the primary source of emissions. Energy burned to run cars and trucks, heat homes and businesses, and power industries is responsible for about 80 percent of global carbon dioxide emissions, about 25 percent of United States methane emissions, and about 20 percent of global nitrous oxide emissions[6]. Increased agriculture and deforestation, landfills, and industrial production and mining also contribute a significant share of emissions.

The United States, which is home to less than 5 percent of the earth's population, produces 25 percent of the world's carbon dioxide emissions and is the largest single national source of fossil fuel-related carbon dioxide emissions in the world reaching an all-time high of 1592 million metric tons of carbon in 2002. In the United States, approximately 6.6 tons (almost 15,000 pounds carbon equivalent) of greenhouse gases are emitted per person per year[7]. United States fossil fuel emissions are 66 percent higher than those of the world's second largest emitter, the People's Republic of China. Emissions in 2002 rose less than 1 percent over 2001 levels and are slightly more than twice those of mid-1950s levels, although the United States share of global emissions declined from 44 percent to 24 percent over the same interval because of higher growth rates in other countries[8]. Figure 2-2 shows the percentage of carbon dioxide emissions by the world's nations in 1998. Figure 2-3 shows the per capita greenhouse gas emissions by nation for 1995.

Once these carbon-based gases get into the atmosphere, they stay there for decades or longer. Paleoclimate readings taken from ice cores and fossil records show that levels of carbon dioxide and methane, two of the most abundant greenhouse gases, are at their highest levels in the past 420,000 years[9]. Since the industrial revolution, carbon dioxide levels have increased 31 percent and methane levels have increased 151 percent[10]. Figure 2-4 shows the carbon dioxide concentrations in ice core samples obtained by drilling deep into glaciers and polar ice caps and taking out samples of ice, then melting the ice and capturing the gas and measuring the amount of carbon dioxide. As shown, these samples show an increase in carbon dioxide concentrations in the 100 year period from about 1850 to 1950[11]. Figure 2-4 also shows the increase of carbon dioxide levels in air samples collected at the Mauna Loa Observatory in Hawaii since 1975. As shown over the last 30 years, average annual carbon dioxide concentrations have increased from 330 parts per million (ppm) in 1975 to 380 ppm in 2005, representing a 15 percent increase over the period[12].

Many scientists fear that the increased concentrations of greenhouse gases have prevented additional thermal radiation from leaving the Earth, have enhanced the heat-trapping capability of the earth's atmosphere, and are believed to be the cause of global warming and climate change.

EVIDENCE OF GLOBAL WARMING/CLIMATE CHANGE

Overview of Scientific Research

Scientific research has indicated for more than a decade that global warming and regional/global changes to our climate are underway. Technical journals have published peer-reviewed articles on climate change for many years. In August 2005, the Journal of the American Water Works Association published an article putting climate change into a water resources manager's perspective. Many of the technical studies have come to the attention of the federal and State governments.

In June 2005, Governor Schwarzenegger issued Executive Order S-3-05 recognizing the importance of climate change impacts to California, and calling for assessments of climate change impacts and development of mitigation and/or adaptation plans. In December 2005, in response to the Governor's executive order, the California Energy Commission released a draft report, "Climate Warming and Water Supply Management in California." The Public Policy Institute of California conducted a survey, "Special Survey on the Environment", reporting in July 2005 that 86 percent of the California public believes that global warming will affect current or future generations. 2005 was a breakthrough year in wide recognition of the reality of climate change and its potential impacts to Californians.

But even before this recent attention, the World Meteorological Organization and the United Nations Environment Programme established the Intergovernmental Panel on Climate Change (IPCC) in 1988. The role of the IPCC is "… to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation." The IPCC has issued three reports on global climate change, most recently in 2001. A main activity of the IPCC is to provide regular assessments of the state of knowledge on climate change. Three such assessments have been completed. The Third Assessment Report was completed in 2001 and is widely used as a definitive reference. The Fourth Assessment Report will be done in 2007. According to the IPCC web site (http://www.ipcc.ch/about/about.htm), the Second Assessment Report "…provided key input to the negotiations which led to the adoption of the Kyoto Protocol … in 1997."

Major Indicators of Climate Change

There are three major indicators of climate change. They include temperature, receding glaciers and sea level rise. Each of these is described below.

Temperature

The Earth is only 5 to 9°F warmer today than it was 10,000 years ago during the last ice age. Throughout history, major shifts in temperature occurred at a rate of a few degrees over thousands of years, and they were accompanied by radical ecological changes, including the extinction of many species. Temperature data gathered from many different sources all across the globe show that the surface temperature of the Earth, which includes the lower atmosphere and the surface of the ocean, has risen dramatically over the past century. Global mean surface temperatures have increased 0.6 to 1.2°F since the late 19th century, and the fifteen warmest years in the 20th century have all occurred since 1980, and the 1990s were the warmest decade of the entire millennium[13]. In June 2006, the National Academy of Sciences reported that the "recent warmth is unprecedented for at least the last 400 years and potentially the last several millennia." Figure 2-5 shows the increase in global temperature from 1860 to 2000 and for the past 1,000 years for the Northern Hemisphere. Figure 2-6 shows the historic temperature trends by region for 1950 to 1999.

As shown in Figure 2-6, temperatures in the United States have also increased. Pronounced warming has occurred in winter and spring, with the largest increase in the period of March through May over the western United States[14]. In California, over the last century, the average temperature in Fresno has increased 1.4°F, from 61.9°F (1899-1928 average) to 63.3°F (1966-1995 average), and precipitation has decreased by up to 20 percent in many parts of the state[15].

Receding Glaciers and Melting Permafrost

Readings gathered from glaciers reveal a steady recession of the world's continental glaciers. In almost every mountainous region across the world, glaciers are melting. In one basin in Glacier National Park in Montana, for instance, two-thirds of the ice has disappeared since 1850. In the European Alps, ice that had hidden and preserved the remains of a Stone Age man melted for the first time in 5,000 years. In Africa, 82 percent of the ice on Mount Kilimanjaro has disappeared since 1912, with about one-third melting in just the last dozen years.

Since 1950, the Antarctic Peninsula has warmed by 4°F, four times the global average increase. Since 1995, more than 5,400 square miles, an area equal to Connecticut and Rhode Island combined, have broken off the Antarctic ice shelves and melted. In 2002, a Rhode Island-sized section of the Larsen B ice shelf, which sits offshore of the Antarctic Peninsula, disintegrated in only 35 days. In 2003, the Ward Hunt Ice Shelf, the largest in the Arctic, broke in two. Overall, since the 1950's, the surface area of the Arctic's sea ice has shrunk by 10 to 15 percent in spring and summer, and the ice has thinned by about 40 percent in late summer and early autumn. Taken together, all of these data suggest that over the last century the planet has experienced the largest increase in surface temperature in 1,000 years[16].

Sea Level Rise

Worldwide measurements of sea level show a rise of 0.1 to 0.2 meters (4 to 8 inches) over the last century, ten times the average rate over the past 3,000 years (0.4 to 0.8 inches; about ½ to ¾ of an inch).

Figure 2-7 shows the sea level measurements collected at Fort Point in San Francisco since before 1900, from the longest continuous sea level record for any site on the west coast of North America, showing an approximate 8-inch increase in average sea level since 1900. This record was recently analyzed by United States Geological Survey scientists, who found that four major factors influence sea level at Fort Point: Daily tides, annual sea-level cycles, a long-term trend of slowly rising sea level (shown by the red line on Figure 2-7), and the occurrence of atmospheric events such as El Niños and La Niñas[17].

Other Evidence of Global Warming

Other evidence of global warming includes increased intensity of precipitation events and around the world. Figure 2-8 shows global precipitation changes from 1900 to 1994.

The year 2005, in particular, included many events that some scientists believe provide a preview of future conditions if global warming/climate change continues.

- A series of ferocious hurricanes (including Hurricanes Katrina and Rita) pummeled the Gulf Coast, Mexico, Central American and the Caribbean, causing deadly floods and catastrophic mudslides;
- America's western region saw its second worst wildfire season since 1960; and
- The Arctic ice cap shrank to its smallest size on record.

Recent Events in California

In California and throughout western North America, signs of a changing climate are evident. During the last 50 years, winter and spring temperatures have been warmer, spring snow levels in lower- and mid-elevation mountains have dropped, snowpack has been melting one to four weeks earlier, and flowers are blooming one to two weeks earlier.

There are also a number of large-scale changes that we have seen in the West in the past few decades that may be an indication of climate change. For example, the California drought during the period 1987-1994 was the first prolonged drought since the 1930s. The continuing "west-wide" drought on the Colorado River is unprecedented in recorded history.

There is a great deal of information published by academic and governmental scientists noting a variety of impacts we are seeing in both the short-term and long-term that are associated with global warming and resulting impacts on climate. Perhaps the most compelling for California is the so-called "Roos Ratio", developed by California Department of Water Resources (DWR) Chief Hydrologist Maurice Roos, and presented at the September 2005 conference "Urban Water Supplies and Climate Change in the West", sponsored by the Southern Nevada Water Authority, Desert Research Institute, and the Natural Resources Defense Council. A number of years ago, Mr. Roos began evaluating the April-July snowmelt runoff from the Sierra Nevada. He concluded that there appeared to be a long-term declining trend that could have profound implications to water resources management in California. Data from the Sacramento River system for the period 1906-2004 is shown in Figure 2-9[18]. This figure depicts a marked decline in April-July runoff as a percent of total annual runoff.

In California, 2005 was a very wet year, and these conditions continued into 2006. Major storms led to record precipitation and snowfall in January 2005. In December 2005 and January 2006, the largest rainfall totals since 1997 occurred in many parts of northern California and led to damaging floods and mudslides. Snow fell in the highest locations of the Sierras, while warmer weather produced rain in many mid-elevation locations that had previously received snow in early December[19].

WHAT MIGHT HAPPEN IN THE NEXT 100 YEARS?

Potential Future Global Climate Changes

For a given concentration of greenhouse gases, the resulting increase in the atmosphere's heat-trapping ability can be predicted with some confidence, but the resulting impact on climate is more uncertain. The climate system is complex and dynamic, with constant interaction among the atmosphere, land, ice, and oceans.

General circulation models are complex computer simulations that describe the circulation of air and ocean currents and how energy is transported within the climate system. While uncertainties remain, these models are powerful tools for studying climate. Many scientists are reasonably confident about the ability of models to characterize future climate at continental scales.

Recent model calculations suggest that global surface temperature could increase an average of 1.6 to 6.3°F by 2100, with significant regional variation[20]. These temperature changes would be far greater than recent natural fluctuations, and they would occur significantly faster than any known changes in the last 10,000 years. However, according to a September 2006 draft of IPCC's Fourth Assessment Report, if greenhouse gas emissions are held at current levels, the average global temperature increase could be contained to 3.6°F by 2100. If no action is taken to reduce emissions, the average global temperature is projected to increase by 5.4°F by 2100 [21].

The models suggest that the rate of evaporation will increase as the climate warms, which will increase average global precipitation. They also suggest increased frequency of intense rainfall, and a marked decrease in soil moisture over some mid-continental regions during the summer[22].

As shown on Figure 2-10, global sea level was projected to increase by 6 to 38 inches by 2100[23], up to four times the 4 to 8 inch increase during the 20th century. However, according to the September 2006 draft of IPCC's Fourth Assessment Report, sea level increases are now forecasted to only increase between 5.5 and 17 inches by 2100[24]. The rise will be mainly due to seawater expanding from increased ocean temperatures and run-off from the melting of continental glaciers and a slight melting of the Greenland Ice Sheet.

Some human activities may help offset global warming. For example, scientists estimate the increased presence of atmospheric aerosols have offset global warming due to greenhouse gases by as much as 40 percent. When fossil fuels burn, they not only release greenhouse gases, but also sulfur dioxide. The sulfur dioxide gets into the air and mixes with oxygen to create sulfate aerosol particles, which reflect sunlight. Aerosols only stay in the air anywhere from a few days to a few weeks, whereas greenhouse gases can remain anywhere from years to decades. Still, in places like the eastern United States, Africa, Brazil, China and the Indian subcontinent, where particulate pollution is quite heavy at times, aerosols can significantly cool the surface[25]. However, because fewer sulfate aerosols are being produced in the United States, the United States is projected to warm more than the global average.

Potential Future California Climate Changes

Calculations of regional climate change are much less reliable than global ones, and it is unclear whether regional climate will become more variable. However, many scientists believe that the frequency and intensity of some extreme weather (e.g., droughts, floods, and frosts) could increase. Over the next century, California's climate may change even more. The latest projections, based on state-of-the-art climate models, indicate that if global heat-trapping emissions proceed at a medium to high rate, temperatures in California are expected to rise 4.7 to 10.5°F by the end of the century. In contrast, a lower emissions rate would keep the projected warming to 3 to 5.6°F[26].

Appreciable increases in precipitation are projected: 20 to 30 percent (with a range of 10 to 50 percent) in spring and fall, and somewhat larger increases in winter. Little change is projected for summer. The amount of precipitation on extreme wet days most likely would increase, especially in the winter and fall, and there could be a decrease in the number of long dry spells and an increase in the number of long wet spells[27].

There are a number of climate models in use, and they show a wide range of potential future conditions. Figure 2-11, from DWR Director Lester Snow's September 2005 presentation referenced earlier, shows a range of projected changes in annual precipitation in northern California as a percentage of "normal" precipitation for the period 1951-1980.

Climate models have also been utilized to predict increases in streamflow in key California rivers. Figure 2-12 shows probabilities of increased peak daily flow (above average water flow) in the Sacramento and American Rivers over the next 100 years. These models suggest increased flow and increased flooding in the future, with peak flows potentially increasing by as much as 150 percent[28].

Potential Impacts of Future Climate Changes

Global climate change poses risks to human health and to terrestrial and aquatic ecosystems. Important economic resources such as agriculture, forestry, fisheries, and water resources also may be affected. Along much of California's coast, sea level is already rising by 3 to 8 inches per century (e.g. 1990 to 2000) (see Figure 2-7). However, if heat-trapping emissions continue and temperatures rise, sea level is expected to rise another 5.5 to 17 inches by 2100[29]. Warmer temperatures, more severe droughts and floods, and sea level rise could have a wide range of impacts including:

- Higher temperatures and increased frequency of heat waves may increase the number of heat-related deaths and illnesses.
- As temperatures rise, disease-carrying mosquitoes and rodents may continue to move into new areas infecting people with dengue fever, malaria, hantavirus, West Nile virus, and other infectious diseases.
- Climate change could increase concentrations of ground-level ozone and contribute to larger areas not meeting national health standards for air quality.
- Sea level rise could lead to flooding of low-lying property, loss of coastal wetlands, erosion of beaches, saltwater contamination of drinking water, and increased vulnerability of coastal areas to storms and flooding.

In particular, global climate change could have significant impacts on water demands and supplies, including:

- Due to increased evaporation, warmer climates and less soil moisture may increase the need for irrigation water for agriculture, but, at the same time, could decrease water supplies.

- Higher snow levels and less snowpack would lead to less spring runoff. At the September 2005 conference "Urban Water Supplies and Climate Change in the West," DWR Director Lester Snow stated the following: "A 3°C (5.4°F) rise in temperature over the next century (a 'moderate' projection) is expected to increase the snow elevation by about 1,500 feet. This could result in a loss of water storage in the Sierra snow pack on the order of 4 to 5 million acre-feet." To put this into further perspective, the potential snow pack storage loss is equivalent to the 4.5 million acre-feet storage capacity of Shasta Reservoir.
- Increased evaporation could result in lower river flow and lower lake levels, particularly in summer. If streamflow and lake levels drop, groundwater recharge would be impacted, and groundwater supplies could also be reduced.
- Winter runoff most likely would increase, while spring and summer runoff would decrease. This could be problematic because existing reservoirs may not be large enough to store the increased winter flows for release in the summer during hotter, higher demand periods.
- More intense precipitation and higher sea level elevations could increase flooding. In particular, the fragile environment of the Delta and its levee system network could be at risk from increased flooding and the upstream migration of saltwater from the bay. The potential impacts of global warming on the Delta are discussed in more detail in Section 3 of this report.

CONCLUSIONS REGARDING CLIMATE CHANGE

A general consensus is forming among scientists that climate change is real and its overall effects are detrimental. The IPCC has concluded by consensus that "increasing concentrations of anthropogenic greenhouse gases have contributed substantially to the observed warming over the past 50 years." In June 2006, the National Academy of Sciences reported that the Earth is the hottest it has been in at least 400 years and that human activities are responsible for much of the recent warming.

Although individual events or phenomena may not always be easy to link to climate change, the increase in frequency and intensity of such phenomena, and their simultaneous occurrence around the world, provides stronger evidence for such a linkage. Furthermore, many of the recently observed weather events have been the worst or unprecedented in the last 100, 500, 1,000 years or more. This suggests that something highly unusual is happening to our planet.

However, there are still some prominent scientists who feel that the threat of global warming (or climate change) has been greatly exaggerated. Major points of contention include the following:

- Some researchers feel that the historic temperature data, especially pre-1970 data, remain too unreliable to take at face value due to inconsistent measurement and human error, and do not give a clear depiction of historic ocean temperatures.

- No one has ever proven outside of the laboratory whether global warming occurs as a result of carbon dioxide. Scientists have ample fossil evidence that shows that carbon dioxide levels in the atmosphere have risen as the Earth grows warmer, but no one has yet shown that a rise in carbon dioxide is responsible for the past temperature increases. It is possible that the warming in the distant past could have triggered the rise in carbon dioxide.
- The models being used by researchers to forecast future global warming have many uncertainties, and it is not clear whether climatic change can be predicted by these models.

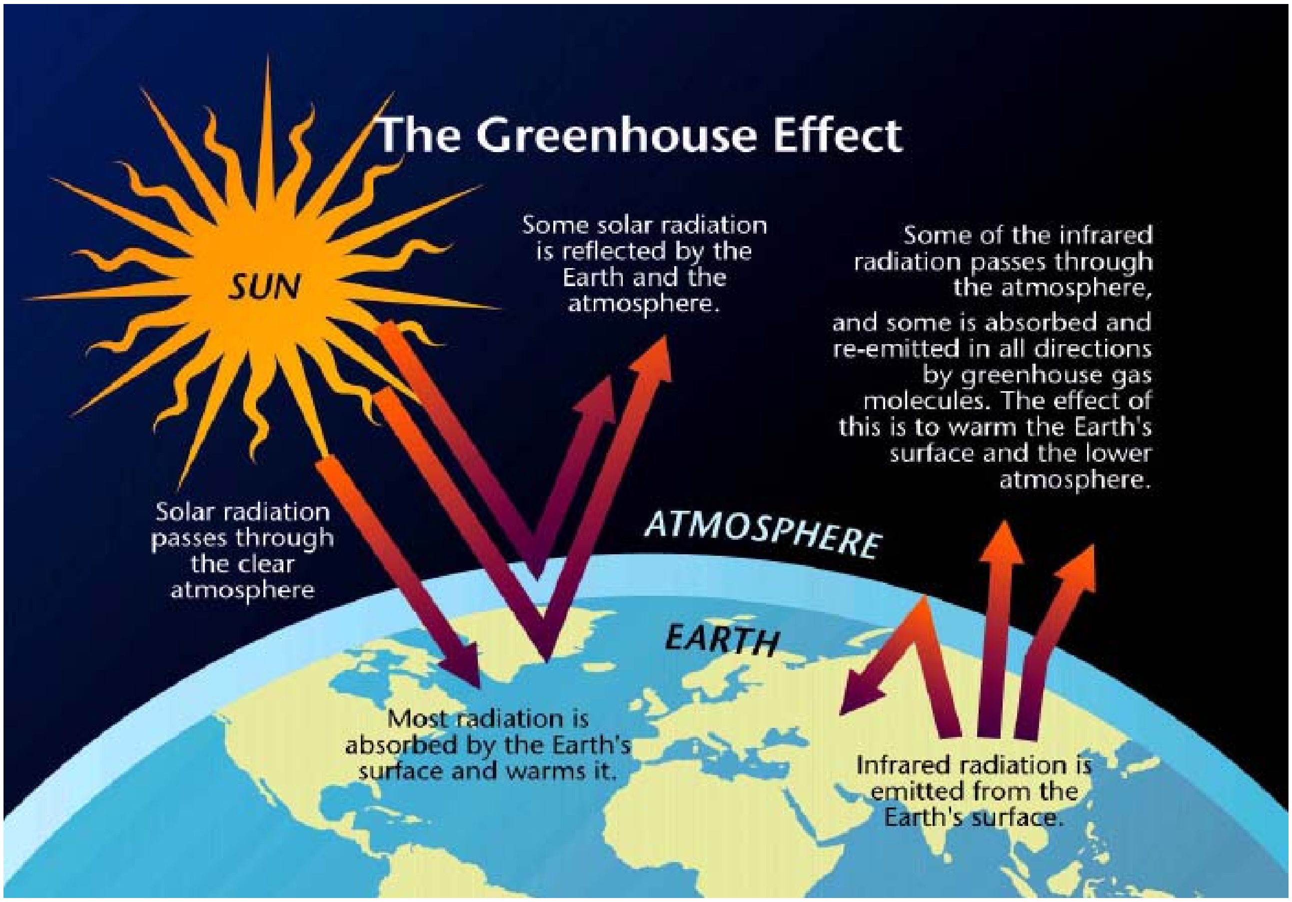

Figure 2-1. The Greenhouse Effect

Source: National Assessment Synthesis Team, 2001. Climate Change Impacts on the United States. Report for the United States Global Change Research Program, Cambridge University Press.

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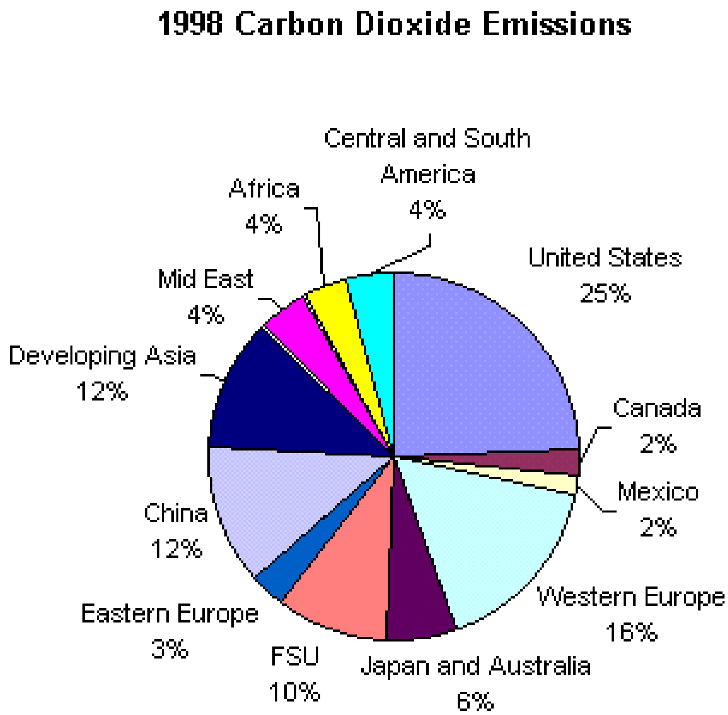

Figure 2-2. 1998 Carbon Dioxide Emissions

Source: USEPA Website: www.yosemite.epa.gov, Global Warming-Emissions page, March 2006.

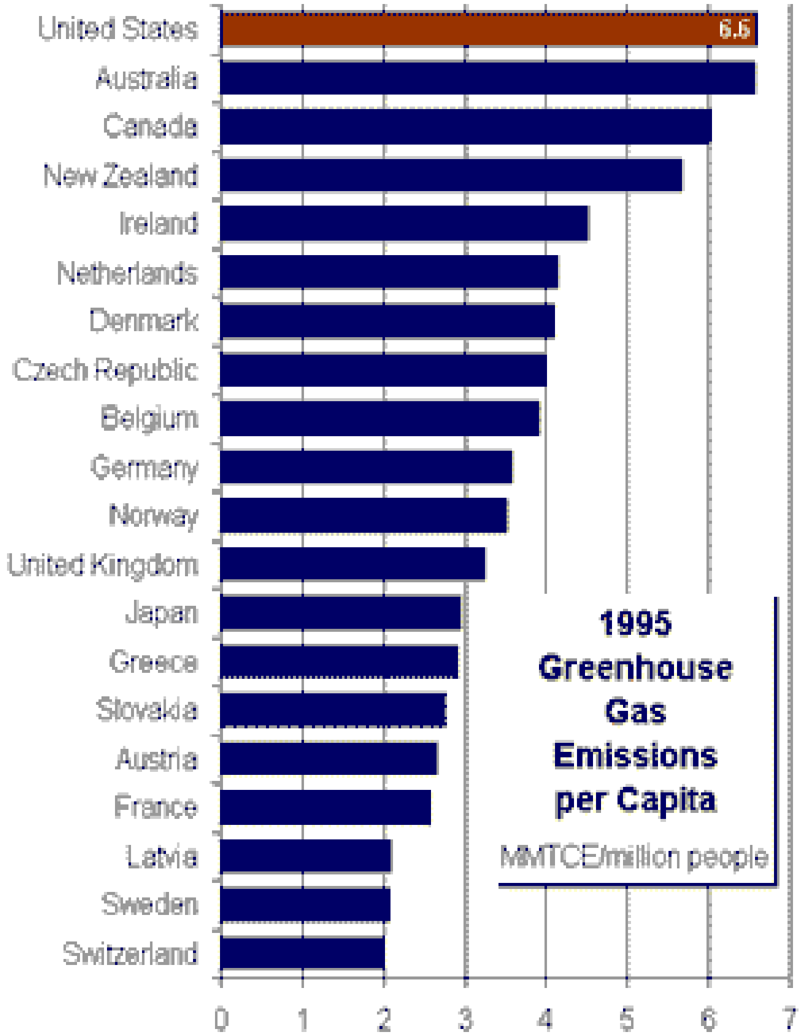

Figure 2-3. 1995 Per Capita Greenhouse Gas Emissions

Source: USEPA Website: www.yosemite.epa.gov, Global Warming-Emissions page, March 2006.

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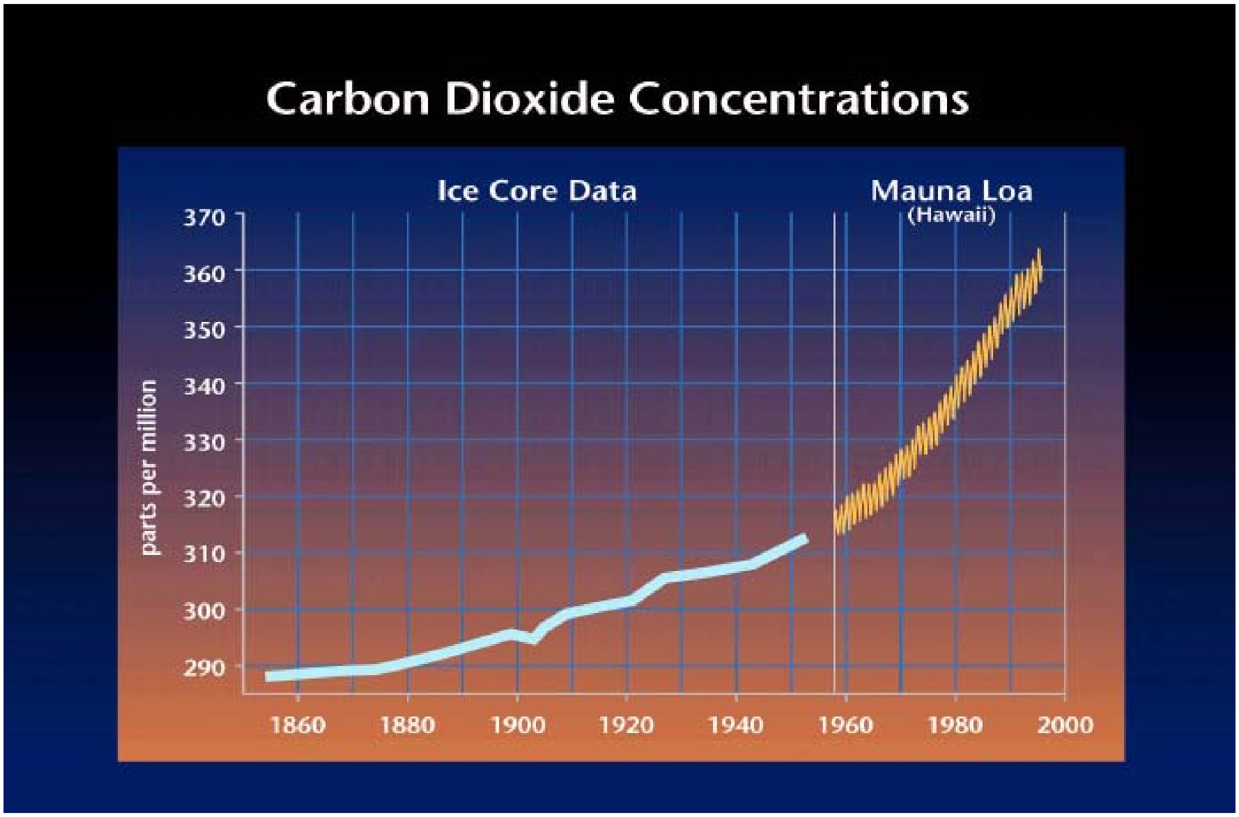

Figure 2-4. Carbon Dioxide Levels in Ice Cores and at Mauna Loa Observatory, Hawaii

Source: National Assessment Synthesis Team, 2001. Climate Change Impacts on the United States. Report for the United States Global Change Research Program, Cambridge University Press.

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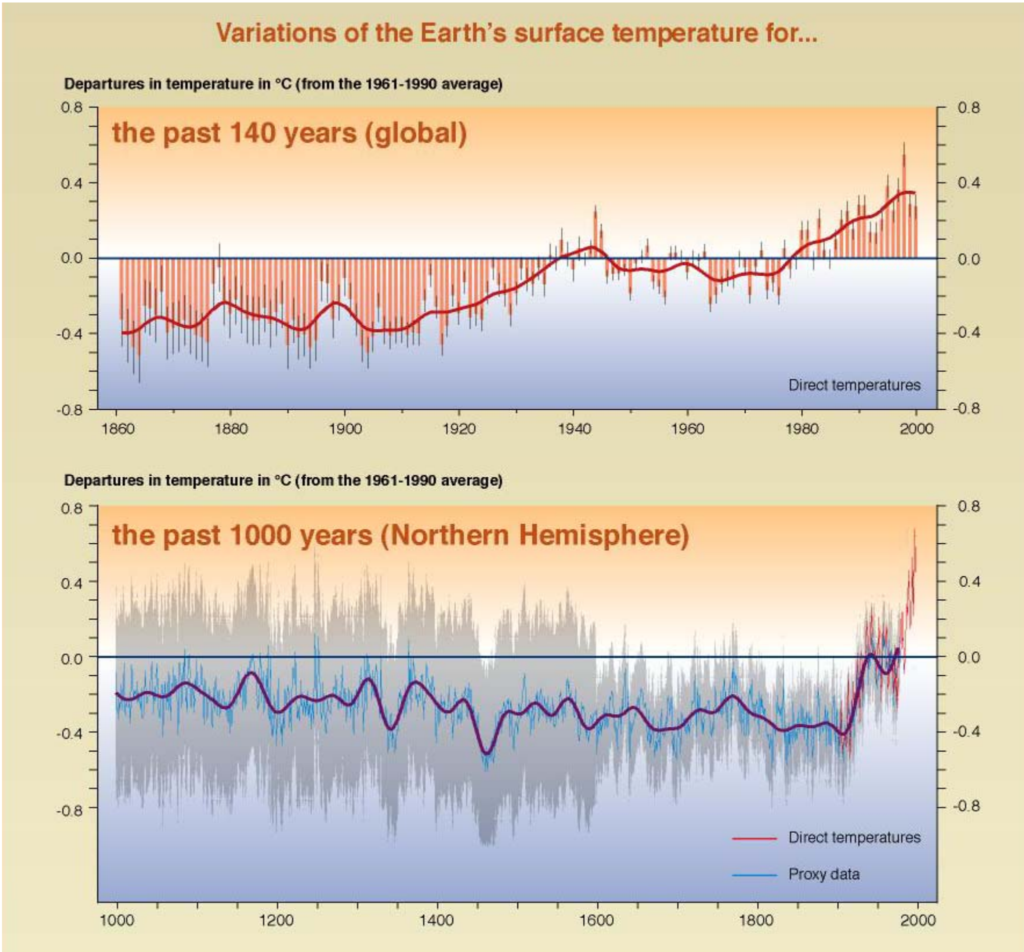

Figure 2-5. Historic Global Surface Temperatures (1860-2000)

Source: Intergovernmental Panel on Climate Change (IPCC) Website, Climate Change 2001 Synthesis Report

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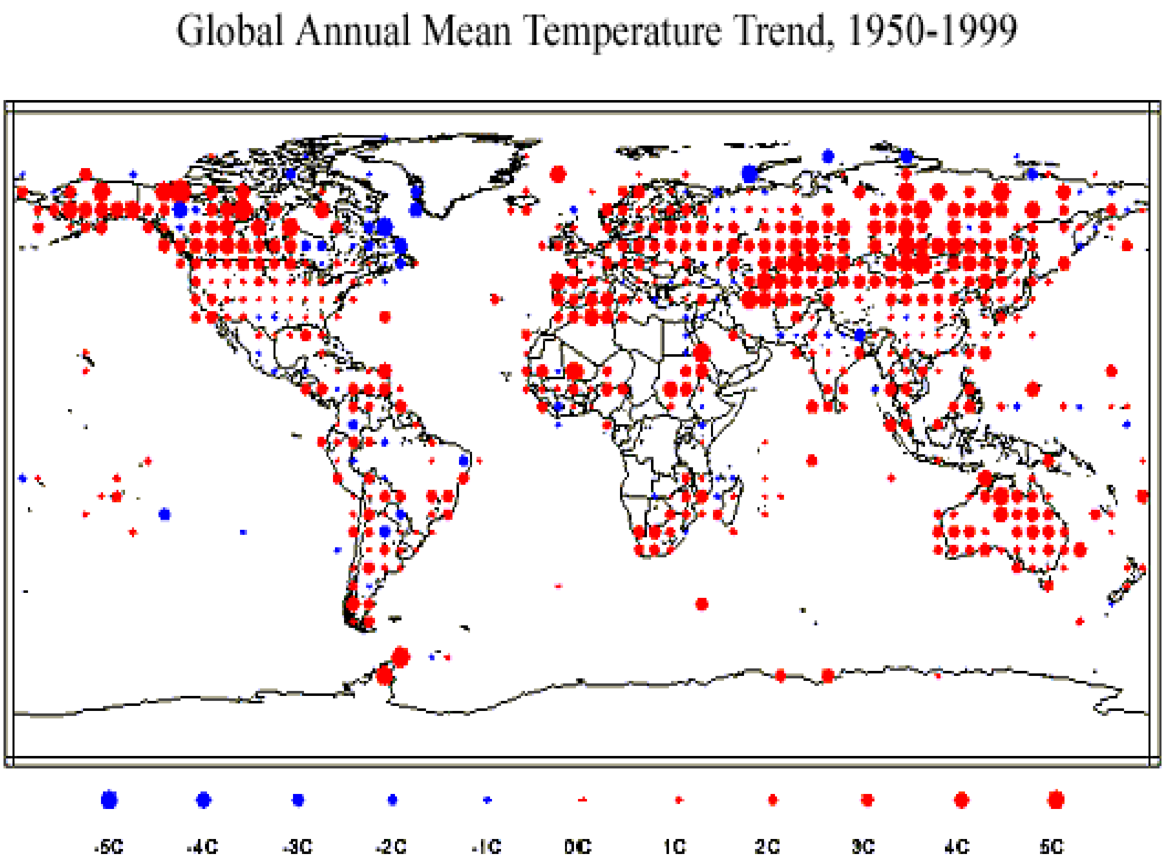

Source: Global Historical Climate Network,
National Oceanic and Atmospheric Administration

Red circles reflect warming — blue circles reflect cooling

Figure 2-6. Global Temperature Trends (1950-1999)

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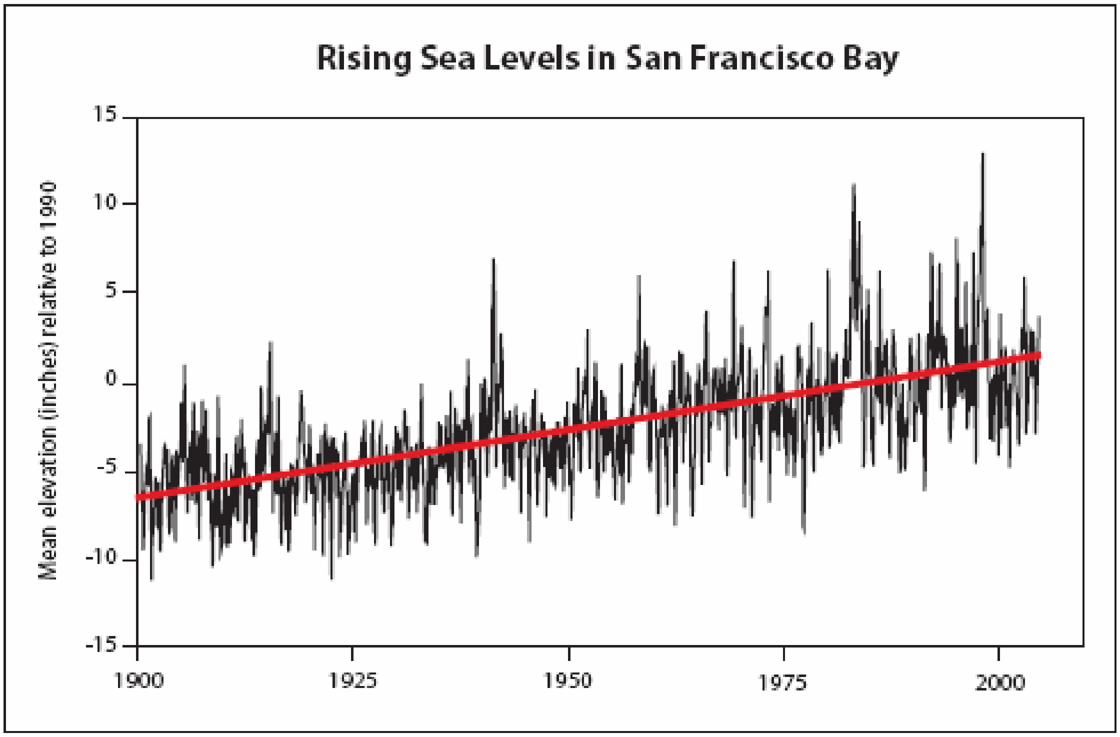

Figure 2-7. Historic Sea Level at Fort Point, San Francisco (1900-1999)

Source: "Our Changing Climate: Assessing the Risks to California," A Summary Report from the California Climate Change Center, July 2006.

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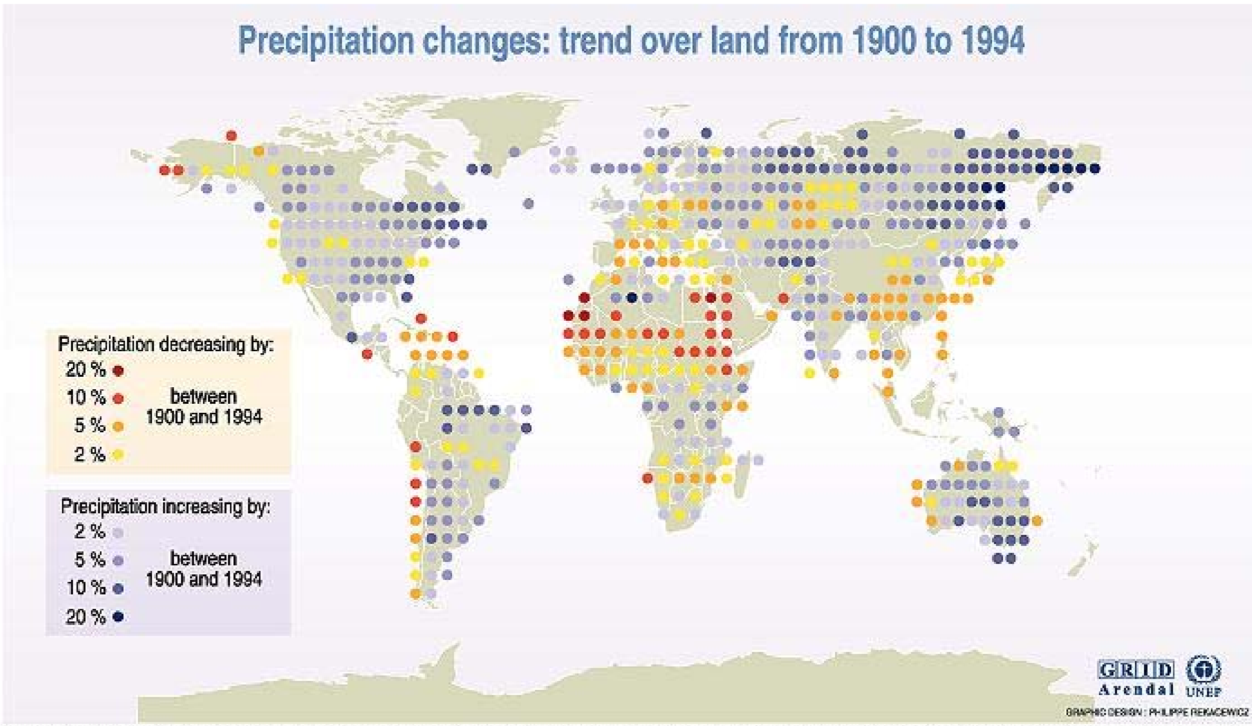


Sources: Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996; Hulme et al., 1991 and 1994; Global Historical Climate Network (GHCN), Vose et al., 1995 and Eischeid et al., 1995)

Figure 2-8. Historic Global Precipitation Changes (1990-1994)

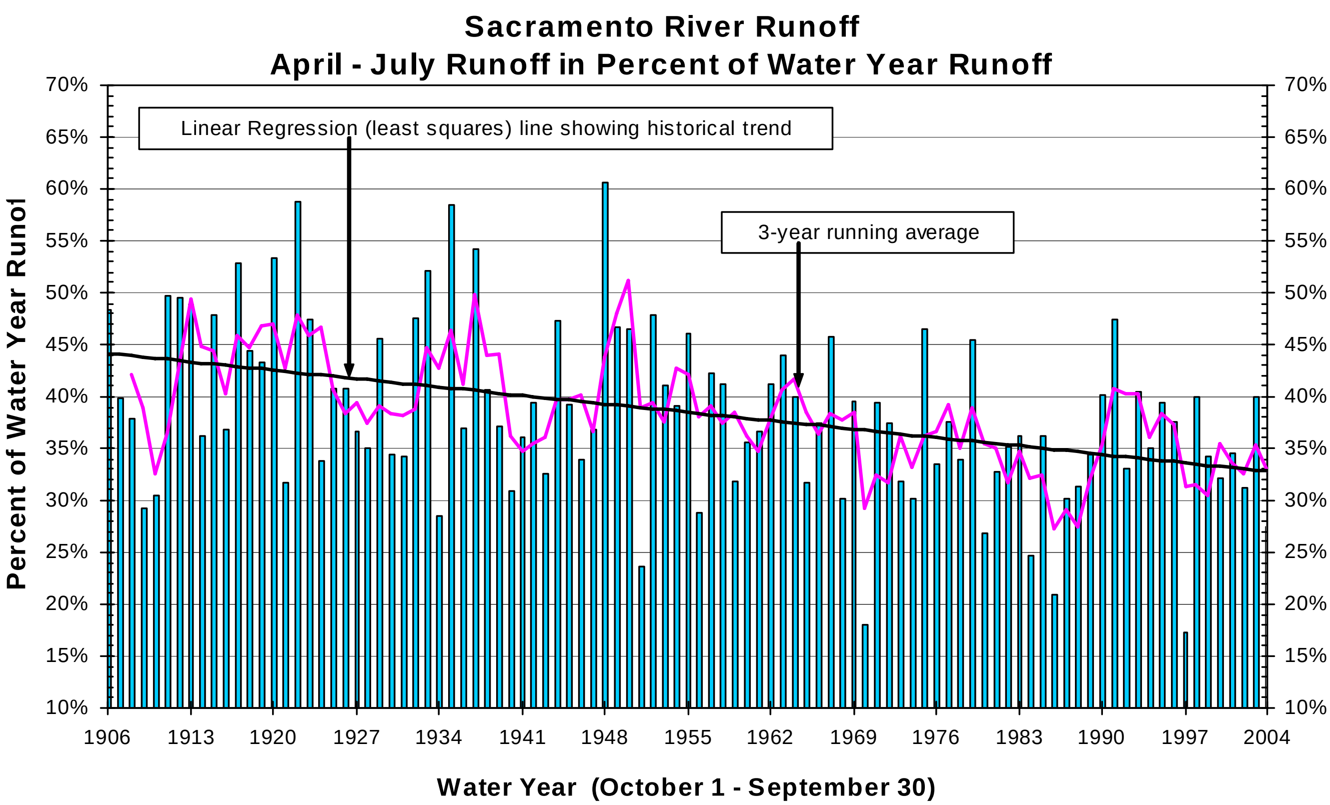
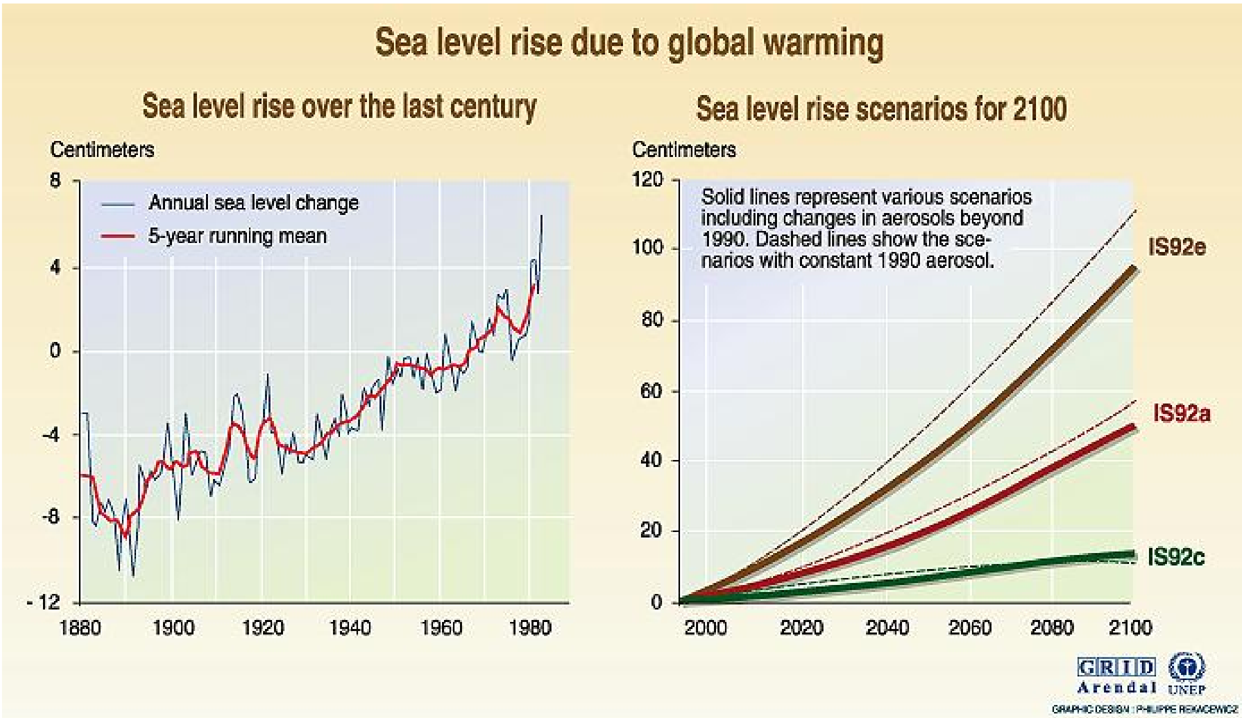


Figure 2-9. Sacramento River April to July Runoff (1906-2004)

Source: Department of Water Resources Chief Hydrologist Maurice Roos, presented at the September 2005 conference "Urban Water Supplies and Climate Change in the West"



Source: Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996; Sea level rise over the last century, adapted from Gornitz and Lebedeff, 1987.

Figure 2-10. Historic and Potential Future Sea Level Rise

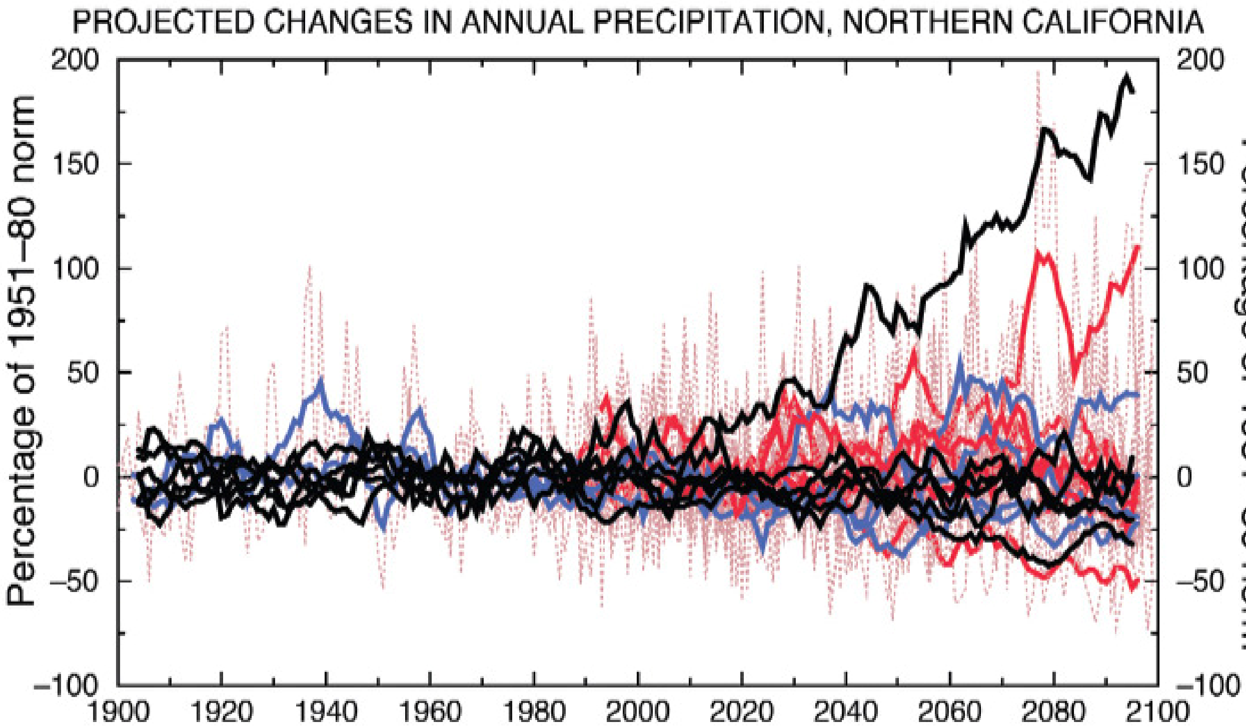


Figure 2-11. Projected Changes in Annual Precipitation in Northern California

Source: Department of Water Resources Chief Hydrologist Maurice Roos, presented at the September 2005 conference "Urban Water Supplies and Climate Change in the West"

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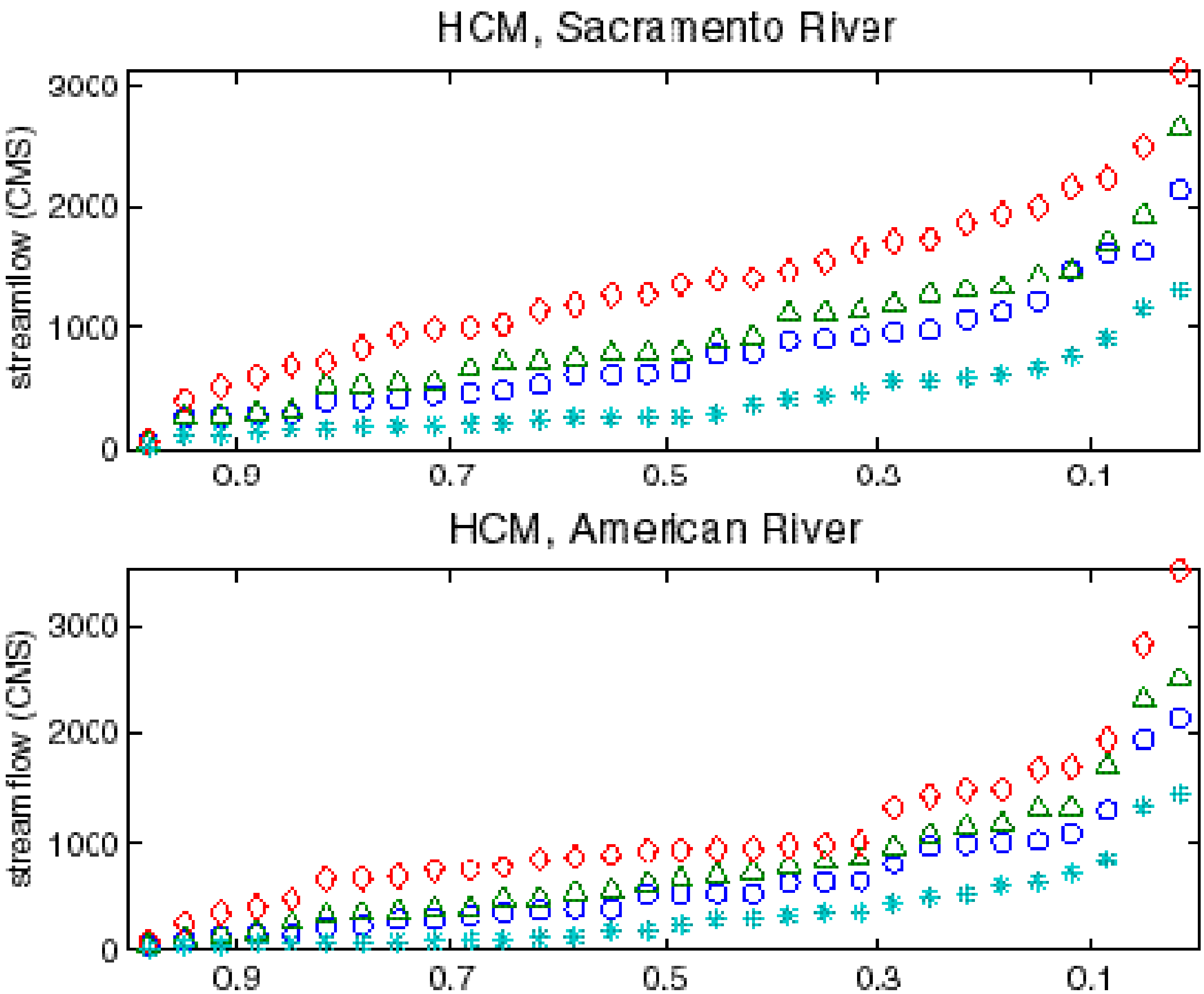

Notes:

The blue circles represent increases that are projected to occur between 2010 and 2039. The green triangles represent increases in flow projected between 2040 and 2079. The red circles are projected increases between 2080 and 2100.

HCM = Hadley Climate Model 2

Figure 2-12. Potential Increases in Streamflow

Credit: Norman Miller, Lawrence Berkeley National Laboratory

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SECTION 3. POTENTIAL CLIMATE CHANGE IMPACTS TO THE DELTA

OVERVIEW OF THE SACRAMENTO-SAN JOAQUIN DELTA

The Sacramento-San Joaquin Delta (Delta) is a largely rural area in a complex maze of tributaries, sloughs, islands, a transportation network (including roads, railroads, and navigation channels) and an altered remnant of the largest estuary on the West Cost. It is a haven for plants and wildlife, supporting more than 750 plant and wildlife species. The Delta supports a population of more than 400,000 people in the cities of Antioch, Brentwood, Isleton, Pittsburg, and Tracy within the Delta, and in other cities adjoining the Delta such as Sacramento, Stockton and West Sacramento.

The Delta is the largest estuary on the West Coast and consists of about 738,000 acres of land in six counties interlaced with hundreds of miles of waterways and is segregated into 70 islands, most of which have land surfaces at or below mean sea level[30]. These islands and tracts are protected from the constant threat of inundation by about 1,100 miles of levees. Figure 3-1 provides an overview of the Delta and its facilities.

WHY IS THE DELTA IMPORTANT?

The Delta is a unique and valuable resource and an integral part of California's water system. It receives runoff from over 40 percent of the State's land area including flows from the Sacramento, San Joaquin, Mokelumne, Cosumnes, and Calaveras rivers[31]. The Delta provides habitat for over 750 species of fish, birds, mammals, and plants; supports agricultural and recreational activities; and is the focal point for water distribution throughout the State.

As the hub of California's two largest water distribution systems, the Bureau of Reclamation's Central Valley Project (CVP) and California's State Water Project (SWP), the Delta is critical to the national economy because it protects and channels the drinking water for two-thirds of the state (for more than 23 million people) and irrigation water for over 7 million acres of some of the most highly productive agricultural land in the world[32].

The Delta is also critical to the Bay Area. In the North Bay, Delta water supplies are conveyed via the North Bay Aqueduct (NBA) to residents and businesses in Napa and Solano counties, including the cities of Napa and Vallejo. In the South Bay, Delta water supplies are conveyed via the SWP South Bay Aqueduct (SBA) to Alameda County Flood Control and Water Conservation District (Zone 7), Alameda County Water District and Santa Clara Water District.

On average, approximately 75 percent of Zone 7's water comes from the Delta via the SBA[33].

DELTA LEVEES

Levee System Overview

Of the 1,100 miles of levees in the Delta, 385 miles are "project" levees, which are levees that were improved and incorporated into the Sacramento and San Joaquin County Flood Control Projects and are located at the perimeter of the Delta along the Sacramento and San Joaquin Rivers. The rest of the Delta levees are "non-project" levees and generally do not meet Federal project levee standards. Local reclamation districts maintain both "project" and "non-project" levees with assistance from the State[34].

DWR inspects and evaluates the maintenance on all of the State's federally designated "project" levees and channels. Where the levees provide broad system benefits, and local interests are unable to perform satisfactory maintenance, DWR may perform the levee maintenance if required. Maintenance performed by DWR on behalf of local interests is funded through assessments of benefiting landowners[35].

Many of the levees in the Delta, originally built to dry out land for agricultural use, were generally not built with engineering specifications. They were built to differing standards, belong to different owners, and are overseen by dozens of reclamation districts[36].

Deteriorating Conditions of Delta Levees

The aging Delta levee system is subject to risks from high inflows during storm events, high tides (particularly during high flow events), high winds, low capacity of adjacent channels due to sedimentation, earthquakes, wind waves and erosion, waves generated by boat and ship traffic, subsidence, under seepage, burrowing animals, sea level rise, and inadequate maintenance practices and funding.

The problems that the Delta levee system faces are aggravated by the fact that these levees were built on poor foundations, mostly organic soils, and by the manner in which they were built, most without an engineered design. As the levees were constructed over the past 150 years, most were made of the material dredged from the adjacent river and channel bottoms without the benefit of modern methods and appropriate borrow materials. The levees were built mainly to protect crops and other agricultural land use, not to protect human lives and the urbanization that came in more recent years. Further complicating the situation, these levees are unusual in comparison to typical flood control levees in that they are holding water all the time, since they are located on tidal channels and protecting islands that are below sea level (due to subsidence) by as much as 25 feet (see Figure 3-2). For all these reasons, maintenance of Delta levees is very difficult and very costly[37].

The U.S. Army Corps of Engineers (COE) has pinpointed over 30 erosion sites on Delta levees[38]. In the Sacramento area, a COE levee survey completed in 2003 found that 89 miles of levees needed significant repairs. While many of those improvements have since been made, flood protection in Sacramento is still half of what New Orleans had before Hurricane Katrina, with California levees built to withstand floods predicted to occur once in every 100 years and New Orleans' levees built to a 250-year standard[39]. Since the 2003 evaluation, the COE has developed new seepage design criteria that will require much more stringent field exploration than earlier guidance. These new criteria are likely to result in identifying many more deficient areas that will in turn ultimately lead to a significantly greater repair cost[40].

In the Delta, many of the non-project levees, many founded on peat soils, have problems associated with long-term levee settlement and island subsidence. Each of the Delta's 70 islands and tracts has flooded at least once since they were originally dewatered[41]. During the last century there have been more than 162 levee failures and island inundations, most of which occurred during flood seasons[42].

More recently, a levee on Upper Jones Tract failed without warning on a sunny day in June 2004. Although the exact cause remains unknown, the prime suspect in the failure is a beaver[43]. The levee failure inundated 2,000 acres of farmland[44]. The cost for emergency response, damage to private property, lost crops, levee repair, and pumping water from the island totaled nearly $100 million. There were also significant costs associated with losses in water supply and conveyance. Following the break, Delta pumping was curtailed for several days to prevent seawater intrusion at the State and Federal pumping plants. Water demands were met through unscheduled releases from San Luis Reservoir, a large off-stream reservoir where water is held after it is pumped from the Delta. Releases were also increased at Shasta and Oroville reservoirs, sending more fresh water to the Delta for salinity control[45].

In 2000, DWR estimated that it would cost about $1.3 billion to improve all Delta levees to CALFED's base level of protection (based on Public Law PL 84-99), which does not even equate to 100-year flood protection[46]. And even after the PL 84-99 improvements are made, the levees would still be susceptible to earthquakes[47].

A "report card" was produced in late February 2006 by the Sacramento chapter of the American Society of Civil Engineers that rated the condition of Central Valley levees based on their condition, past flood performance and future capacity, maintenance, age, flood preparedness, amount of property protected by levees, and presence of a master plan for their improvement. The Delta levees received an "F" grade[48].

Potential Impacts of Levee Failure

Because of the vast area of the Delta and its infrastructure, its vulnerability to an earthquake is higher than that of an individual structure. Shortly after Hurricane Katrina, Lester Snow, director of DWR, outlined what could happen to California in the event of a 6.5-magnitude earthquake occurring on a fault in the West Delta[49,50].

- At the time of the quake, Delta levees would break in about 30 places on 16 islands, flooding homes and farmland.
- 200 miles of levees will be weakened by slumping, cracking and increased seepage; without repairs, these damages will lead to additional levee failures.

- The damage draws saltwater from San Francisco Bay into the Delta (an estimated 300 billion gallons in the first few days), forcing the State Water Project and the Central Valley Project to shut down, and cutting off water delivery to much of the Bay Area, Central California and Southern California.
- Levee damage causes failure of the Mokelumne Aqueduct.
- The flooding damages major power and gas transmission lines, affecting power delivery to the entire state.
- Up to 3,000 homes are inundated.
- 85,000 acres of agricultural land and crops are flooded.
- State Highways 4, 12 and 160 are inundated and railroads are damaged.
- Much of the Delta ecosystem is devastated; it takes at least 15 months to repair the Delta, and the economic impact to the State is about $30 to 40 billion over a five-year period.

Levee failure and subsequent island flooding can cause large amounts of saline ocean water to be drawn into the Delta. Water supply pumping operations in the Delta for the SWP, CVP and other supply systems must stop when a large amount of ocean water is drawn into the Delta and salinity levels in the Delta increase to unacceptable levels. Water supply operations can be restarted only when salinity returns to acceptable levels. Salinity conditions can take many months to return to normal depending on the amount and location of levee failures and hydrologic conditions[51]. According to Professor Jeff Mount, a U.C. Davis geologist, a major levee breach would draw brackish ocean water into the Delta, contaminating irrigation and drinking water supplies and perhaps stopping the southward flow of water supplies for a year or longer[52].

Levee failure would also impact other infrastructure, including rail lines, gas pipelines and highways. Pacific Gas and Electric Company (PG&E) is concerned enough that it is now planning to build a new pipeline in the Delta 100 feet below ground, where it would be out of harm's way in case of what PG&E sees as a real threat of a collapsed levee system[53].

Because exact risks from catastrophic flooding and/or seismic events are unknown, studies are underway in support of the DWR Delta Risk Management Strategy (DRMS) Study, which is scheduled for completion in December 2007[54].

CLIMATE CHANGE IMPACTS TO THE DELTA AND ITS OPERATIONS

Overview of Climate Change Impacts to the Delta

The CVP and the SWP are each operated under strict guidelines, with constraints that have to be met prior to water being available for export from the Delta. Flood control storage in reservoirs, availability of water to water right holders in the upper Sacramento and San Joaquin Rivers, minimum flow requirements in the rivers and the Delta, dissolved oxygen concentration in the Stanislaus River, 800,000 acre-feet per year reserved for restoration of fish, wildlife and habitat restoration and salinity standards in the Delta are all considered in determining CVP and SWP daily pumping operations. Even under existing supply and demand patterns, water requirements can barely be met under dry and critical water years[55]. Therefore, climate change and its impacts, such as those described below, must be considered in developing future operational plans.

Snowpack Changes

California relies on snowpack as a major part of annual water storage. Annual runoff from the Sierra Nevada during April through July averages 14 million acre-feet and comes primarily from snowmelt. As previously discussed, several global climate change scenarios predict significant future reductions in the Sierra snowpack. A reduced snowpack will reduce the total water storage for the state.

Furthermore, changes in the timing of snowfall and snowmelt, as a result of climate change, may make it more difficult to refill reservoir flood control space during late spring and early summer, potentially reducing the amount of surface water available during the higher demand summer season. Changes in reservoir levels will also affect lake recreation, hydroelectric power production, and fish habitat by altering water temperatures and quality. Reductions in snowpack may require changes in the operation of California's water systems and infrastructure, and increase the value of additional flood control space in reservoirs[56].

Shift in Hydrologic Patterns

Historical records reveal long-tem changes in the pattern of April through July runoff (see discussion in Section 2 and Figure 2-9). From the 1950's to present, the percentage of April to July runoff has shown a progressive decline. This may indicate a decline in the amount of water stored annually in the Sierra snowpack leading to reduced spring and early summer river flows[57].

Rainfall Intensity

Research work by Dr. Michael Dettinger of Scripps Institution of Oceanography and Dr. Norman Miller and associates at Berkeley National Laboratory show an increased risk of large storms and flood events for several global climate model scenarios (see Figure 2-12). Since existing flood control facilities in the Central Valley and elsewhere seem to be barely able to accommodate large flood events, like the 1-in-100-year flood, even a modest increase could pose problems. An increase in winter flood control space would conflict with operations for water supply, power and recreation on many of the big multi-purpose reservoirs in California. The total volume of maximum winter flood control space requirements on major Central Valley foothill reservoirs exceeds 5.5 million acre-feet. Increasing winter flood control space generally would make it more difficult to fill reservoirs in the spring. The filling problem would be compounded if spring runoff were also reduced because of smaller snowpacks[58].

Related to flood risk are the rainfall depth-duration-frequency data widely used for designing local storm water control and drainage facilities. It has been suggested that these statistics be updated frequently, at least every 20 years or so, so that climate changes will be gradually incorporated into the record and into the rainfall statistics[59].

Also associated with rainfall intensity are impacts to water quality, as a result of more runoff with more sediment, and increased urban runoff with the potential for increased contaminants entering the water system.

Sea Level Rise

Sea level rise would have a two-fold impact on the Delta:

1. Increased flood potential associated with problems with the levees protecting low-lying land; and
2. Increased salinity intrusion from the ocean, which could degrade fresh water supplies pumped at the southern edge of the Delta or require more fresh water releases to repel ocean salinity.

Many of the central Delta levees are built on unstable peat soil and are vulnerable to high water levels. The potential impact of a sea level rise on these levees depends on the rate in increase. A small rise can probably be tolerated by the levee system; a major rise of one foot or more could cause significant problems. One perspective is that a one-foot rise would transform the current 100-year high tide peak at Antioch, a western Delta station, into about a 10-year event. Thus the rare high event could become a more frequent threat to the Delta levees and the role they play in protecting the Delta[60].

Salinity intrusion associated with sudden levee failure was discussed previously. However, if sea level gradually rises as a result of climate change, more salt water from the Bay will be pushed into the Delta impacting overall water quality and potentially impacting Delta operations.

Summary of Potential Impacts to Water Supply Operations in the Delta

The following provides a summary of the potential impacts of climate change to water supply operations in the Delta, particularly as operations relate to water supply reliability, water quality and flood control.

Water Supply Reliability

- The operation of storage reservoirs could be impacted by shifting runoff and snowmelt patterns, requiring the need for more flood control storage, and making it more difficult to refill reservoir flood control space during late spring or early summer, and potentially reducing the amount of surface water available during the high demand summer season.
- Levee breaks, either as a result of the impacts of climate change or an earthquake, could have adverse effects on Delta water quality and water system operations. Major levee breaks could take months or years to repair, potentially impacting the availability of water supplies from the Delta.

Water Quality

- More intense storms and increased runoff could impact Delta water quality in two ways:
  1. Increased sediment load, and
  2. Increased contaminants from increased urban runoff.
- Sea level rise could push salt water from the Bay into the Delta, impacting overall water quality and potentially impacting Delta operations.
- Levee breaks, either as a result of the impacts of climate change or an earthquake, could cause large amounts of salt water from the Bay to enter the Delta, and would have adverse affects on Delta water quality and water system operations. The salt water intrusion could take months to dissipate depending on the severity of the levee break and the amount of salt water intrusion which occurs.

Flood Control

- Reservoir operations, including the need for more flood control storage space, could be impacted by snowpack changes, shifts in snowmelt patterns and changes in rainfall intensity.
- Deteriorating levees could fail as a result of increased runoff, more intense storms or sea level rise. Failure of the levees would have catastrophic impacts on the Delta, including its islands and water supply operations.

Impacts of Climate Change on the State Water Project and Central Valley Project

On June 1, 2005, Governor Arnold Schwarzenegger issued Executive Order S-3-05 establishing greenhouse gas emissions targets for California and requiring biennial reports on potential climate change effects on several areas, including water resources. In July 2006, DWR published a Technical Memorandum Report entitled "Progress on Incorporating Climate Change into Management of California's Water Resources" (July 2006 Report)[61]. The July 2006 Report describes progress made incorporating climate change into existing water resources planning and management tools and methodologies. The July 2006 Report evaluates four climate-change scenarios, each with warmer temperatures raising the snow level in California mountains, producing a smaller snowpack and more direct winter runoff from rainfall (instead of snowmelt). Table 3-1 summarizes the basic assumptions for each climate change scenario.

Table 3-1. Climate Change Scenario Descriptions[a]

Scenario	Climate Model	Emission Scenario[b]	Description
PCM B1	Parallel Climate Model (PCM)	B1	Weak temperature warming Weak precipitation increase in California
PCM A2	Parallel Climate Model (PCM)	A2	Modest warming Modest drying
GFDL B1	Geophysical Fluid Dynamics Lab (GFDL) v2.0	B1	Modest warming Modest drying
GFDL A2	Geophysical Fluid Dynamics Lab (GFDL) v2.0	A2	Relatively strong warming Modest drying

(a) Source: Table 4.1 Air Temperature and Precipitation Prediction Trends for Four Scenarios, "Progress on Incorporating Climate Change into Management of California's Water Resources," Technical Memorandum Report, California Department of Water Resources, July 2006.

(b) IPCC greenhouse gas emissions scenarios based on global population estimates. Scenario A2 assumes 15 billion people in the year 2100; Scenario B1 assumes 7 billion people in the year 2100.

Some of the main results documented in the July 2006 Report related to climate change impacts on the SWP and CVP include:

- In three of the four climate change scenarios simulated, there were significant shortages in CVP north-of-Delta reservoirs during droughts.
- Changes in annual average SWP south-of-Delta Table A deliveries ranged from a slight increase of about 1 percent for a wetter scenario to about a 10 percent reduction for one of the drier climate change scenarios. Increased winter runoff and lower Table A allocations resulted in slightly higher annual average Article 21[ii] deliveries in the three drier climate change scenarios. However, the increases in Article 21 did not offset losses to Table A. The wetter scenario with higher Table A allocations resulted in fewer Article 21 delivery opportunities and slightly lower annual average Article 21 deliveries.
- Changes in annual average CVP south-of-Delta deliveries ranged from increases of about 2.5 percent for a wetter scenario and decreases of as much as 10 percent for drier climate change scenarios.

[ii] Article 21 water is additional SWP water sometimes available to certain SWP contractors after SWP Table A water deliveries are met.

- For both the SWP and SVP, carryover storage was negatively impacted in the drier climate change scenarios and somewhat increased in the wetter climate change scenario.

Table 3-2 shows the SWP average and dry year Table A deliveries as determined by DWR under the various climate change scenarios.

Table 3-2. SWP Average and Dry Year Table A Deliveries Under Various Climate Change Scenarios[a]

Scenario	Deliveries (thousand ace-feet, TAF)					
	Average Delivery	Single Dry Year (1977)	2-Year Drought (1976-1977)	4-Year Drought (1931-1934)	6-Year Drought (1987-1992)	6-Year Drought (1929-1934)
Base[b]	3,186	222	1,620	1,521	1,786	1,679
% of Max Table A[c]	77%	5%	39%	37%	43%	41%
GFDL A2	2,879	229	892	1,355	1,396	1,554
% of Max Table A[c]	70%	6%	22%	33%	34%	38%
PCM A2	2,964	279	1,049	1,343	1,651	1,458
% of Max Table A[c]	72%	7%	25%	32%	40%	35%
GFDL B1	2,861	285	952	1,386	1,502	1,507
% of Max Table A[c]	69%	7%	23%	34%	36%	36%
PCM B1	3,224	267	1,413	1,870	1,807	1,949
% of Max Table A[c]	78%	6%	34%	45%	44%	47%

(a) Source: Table 4.14 SWP Average and Dry Year Table A Deliveries, "Progress on Incorporating Climate Change into Management of California's Water Resources," Technical Memorandum Report, California Department of Water Resources, July 2006.
(b) Base CalSim II simulation was adapted from one of the studies presented in 2004 by the Bureau of Reclamation in support of its latest Operations Criteria and Plan (OCAP).
(c) Maximum Delta Table A is 4.133 million acre-feet per year (4,133 TAF).

It should be noted that sea level rise effects on water project operations due to greater salt water intrusion under the climate change scenarios were not examined in the July 2006 Report due to lack of existing tools for that type of analysis. However, preliminary analyses were conducted to examine potential salt intrusion for a one foot rise in sea level. Some of the main results documented in the July 2006 Report related to sea level rise include:

- At present sea level, flexibility in the system to modify reservoir operations and Delta exports for the climate change scenarios results in minor impacts to compliance with chloride standards at municipal and industrial intakes.

- A one foot rise in sea level, without any changes to the system operations, would result in chloride concentrations below the 250 mg/L threshold 90 percent of the time at Old River at Rock Slough. These effects would likely be mitigated with operational adjustments which would translate into water supply impacts to the SWP and CVP.
- Maintaining chloride concentrations below the 150 mg/L threshold would be more challenging during critical and dry years, likely requiring dedication of additional water supplies to repulse sea water in order to maintain Delta water quality under sea level rise conditions.

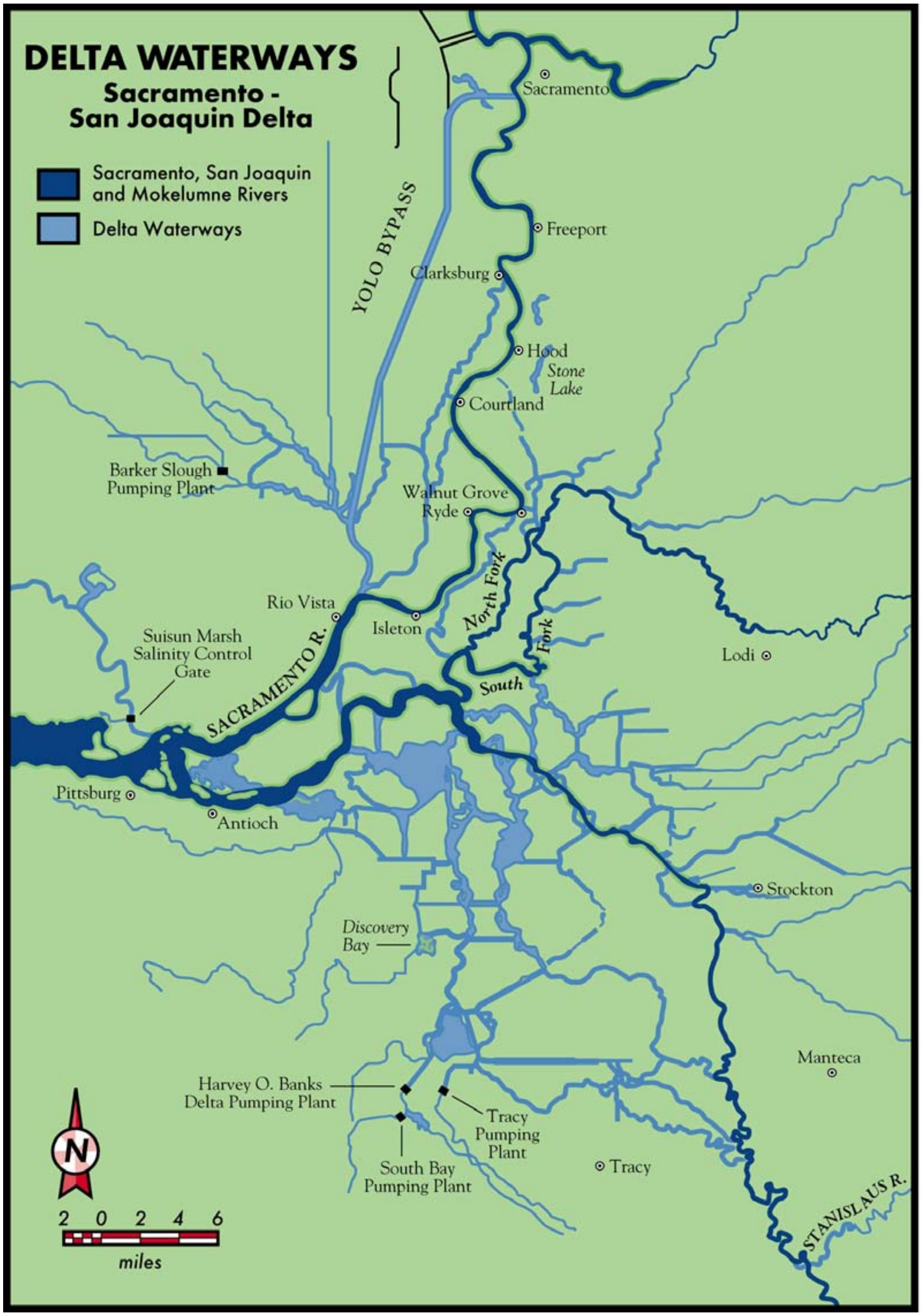

Figure 3-1. Overview of Sacramento-San Joaquin Delta

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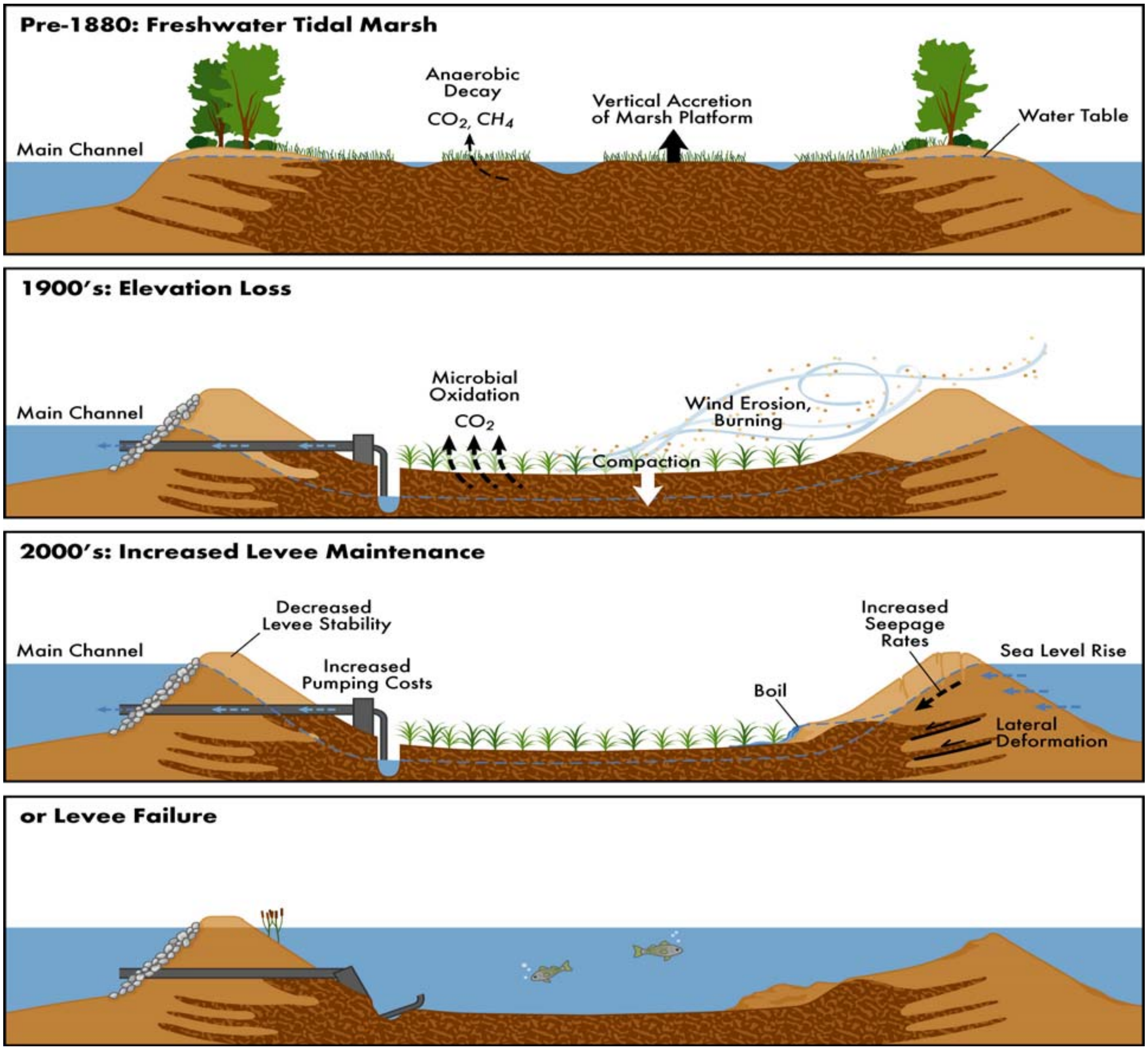

Figure 3-2. Delta Levees Under Various Conditions

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SECTION 4. POTENTIAL IMPACTS TO ZONE 7 WATER SUPPLY RELIABILITY

ZONE 7'S CURRENT WATER SUPPLY RELIABILITY

Zone 7's water supply reliability planning is based on a SWP average annual yield of approximately 75.6 percent of Zone 7's Table A entitlement (80,619 afa), or 60,900 afa, once all SWP Contractors are requesting their full entitlements[62]. DWR's operational studies using the DWRSIM (computer model) under the Monterey Agreement indicate an average future (2020) yield of 75.6 percent (60,900 afa). The "State Water Project Delivery Reliability Report" (finalized in 2003), which uses CalSim II model data, indicates an average long-term yield of 75 to 76 percent (see discussion below)[63]. For planning purposes, Zone 7 has elected to use the average expected SWP delivery (75.6 percent) to estimate long-term sustainable yield from SWP supplies. Although Zone 7's SWP entitlement will generally yield more water in wet years and less in dry years, the use of 60,900 afa (75.6 percent of 80,619 afa) to represent an average year represents Zone 7's expected future yield from the SWP over a long period of time.

Recently, DWR has updated its SWP delivery reliabilities using the CalSim II computer simulation model for existing and future levels of development in the water source areas, assuming historical patterns of precipitation. This updated data was presented in DWR's April 2006 report entitled "The State Water Project Delivery Reliability Report 2005."[64] It should be noted that the updated SWP reliabilities are based on historical hydrology and precipitation data and do not account for future uncertainties such as changes in the climate pattern or levee failure in the Delta due to flooding or an earthquake. Table 4-1 shows the revised SWP Table A deliveries as compared to DWR's previous reliability study completed in 2003.

Although the average SWP delivery has not changed significantly, it should be noted that the difference between the earlier studies and the updated studies for the estimated Single Dry Year deliveries (minimum delivery) is significant. The updated studies have a Single Dry Year delivery of 4 to 5 percent of maximum Table A, compared to 19 to 20 for the studies in the SWP Delivery Report (2003). The lower minimum delivery is primarily due to modification of the delivery-carryover storage rule. Compared to the rule used for the earlier studies, the modified rule reduces delivery by about 80 percent whenever carryover storage (sum of the end-of-September storages of Oroville Reservoir and the SWP share of San Luis Reservoir) is projected to be less than about 860 TAF. The modified rule was developed in coordination with DWR's SWP Operations Control Office to meet the primary objective of reducing the number of years in which Oroville Reservoir storage levels are very low. The minimum delivery occurs in 1977, the driest year in the 73-year simulation.

Table 4-1. SWP Average and Dry Year Table A Delivery from the Delta[(a)]

Study	SWP Table A Delivery from the Delta (in percent of maximum Table A)					
	Average Delivery (1922-1994)	Single Dry Year (1977)	2-Year Drought (1976-1977)	4-Year Drought (1931-1934)	6-Year Drought (1987-1992)	6-Year Drought (1929-1934)
SWP Delivery Reliability Report (2003)						
2001 Study	72%	19%	48%	37%	41%	40%
2021A Study	75%	20%	44%	39%	40%	41%
2021B Study	76%	20%	44%	39%	40%	41%
SWP Delivery Reliability Report (2005)						
2005 Study	68%	4%	41%	32%	42%	37%
2025 Study	77%	5%	40%	33%	42%	38%

(a) Source: Table 5-4 SWP Average and Dry Year Table A Delivery from the Delta, "The State Water Project Delivery Reliability Report 2005," California Department of Water Resources, April 2006.

Table 4-2 shows Zone 7's anticipated deliveries under the updated delivery reliabilities based on Zone 7's current Table A entitlement of 80,619 afa. As shown, average SWP deliveries to Zone 7 would be 77 percent (62,077 afa) in 2025. The 2025 delivery of 77 percent is about 1.5 percent higher than the 75.6 percent long-term average SWP delivery currently assumed by Zone 7.

As described above, during single dry years, the delivery from the Delta drops significantly to 4 to 5 percent of the Table A entitlement, or 3,225 to 4,031 afa for Zone 7. During multiple year droughts, deliveries range from 32 to 42 percent of Table A entitlement, or 25,798 to 33,860 afa for Zone 7. Again, it should be noted that these delivery reliabilities are based on historical hydrology and precipitation and do not account for future climate change.

Table 4-2. Zone 7 Deliveries Under SWP Average and Dry Year Table A Delivery from the Delta[(a)]

Study	SWP Table A Delivery from the Delta (in percent of maximum Table A)					
	Average Delivery (1922-1994)	Single Dry Year (1977)	2-Year Drought (1976-1977)	4-Year Drought (1931-1934)	6-Year Drought (1987-1992)	6-Year Drought (1929-1934)
SWP Delivery Reliability Report (2005)						
2005 Study	68%	4%	41%	32%	42%	37%
Zone 7 Delivery Amount, afa[(b)]	54,821	3,225	33,054	25,798	33,860	29,829
2025 Study	77%	5%	40%	33%	42%	38%
Zone 7 Delivery Amount, afa[(b)]	62,077	4,031	32,248	26,604	33,860	30,635

(a) Source: Table 5-4 SWP Average and Dry Year Table A Delivery from the Delta, "The State Water Project Delivery Reliability Report 2005," California Department of Water Resources, April 2006.
(b) Based on Zone 7 maximum Table A entitlement of 80,619 afa.

POTENTIAL IMPACTS OF CLIMATE CHANGE ON ZONE 7'S FUTURE WATER SUPPLY RELIABILITY

As discussed in Section 3, DWR has begun evaluating the potential impacts of climate change on SWP delivery reliability. Based on climate change scenarios evaluated to date, changes in annual average SWP Table A deliveries ranged from an increase of about 1 percent for a wetter scenario to about a 10 percent reduction for one of the drier climate change scenarios. Assuming a 10 percent reduction in delivery reliability due to climate change, and based on the revised delivery reliabilities discussed above, Zone 7's 2025 average delivery would be reduced from 77 percent to 69 percent (55,869 afa). This average year delivery is significantly lower than the long-term average SWP delivery currently assumed by Zone 7 (75.6 percent, or 60,948 afa).

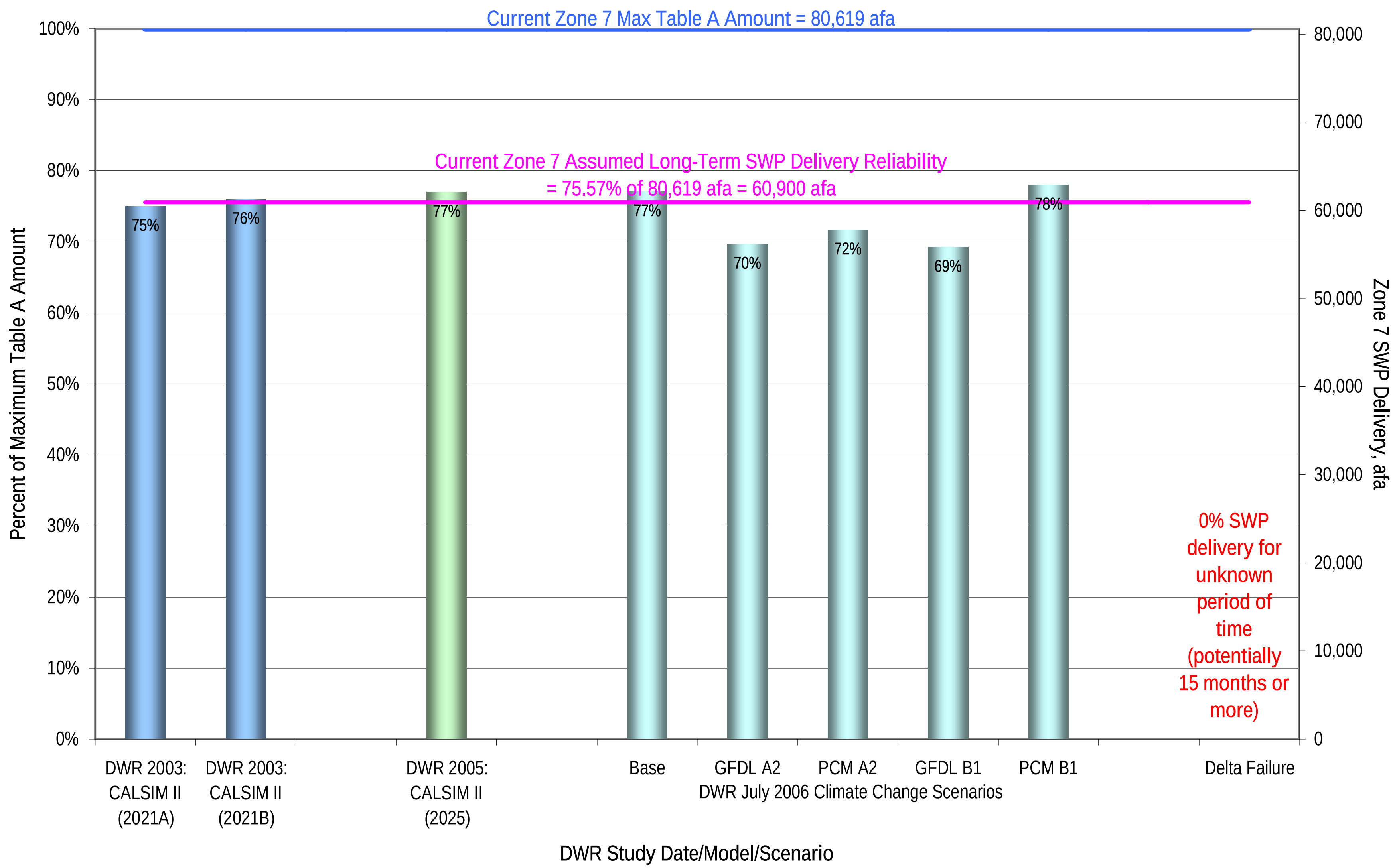
POTENTIAL IMPACTS OF DELTA FAILURE ON ZONE 7'S FUTURE WATER SUPPLY RELIABILITY

As discussed in Section 3, the aging Delta levee system is subject to risks from high inflows during storm events, high tides (particularly during high flow events), high winds, low capacity of adjacent channels due to sedimentation, earthquakes, wind waves and erosion, waves generated by boat and ship traffic, subsidence, under seepage, burrowing animals, sea level rise, and inadequate maintenance practices and funding.

If a major earthquake were to occur in the vicinity of the Delta, the SWP could be shut down for months or even years due to levee failure and saltwater intrusion. Under such a scenario, Zone 7's supply from the SWP would be unavailable, and Zone 7 would need to rely entirely on its other local surface water and groundwater supplies until the SWP system could be restored. As discussed, in Section 3, it could take 15 months or more to repair the Delta after a major earthquake.

Figure 4-1 presents a summary of long-term SWP delivery reliabilities based on the various studies and scenarios discussed above.

Figure 4-1. State Water Project Long-Term Average Delivery Reliability



SWP Reliability Chart
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SECTION 5. POTENTIAL IMPACTS TO OTHER ZONE 7 OPERATIONS

GROUNDWATER MANAGEMENT

Relationship of Various Management Plans

The Main Basin which underlies the Tri-Valley area contains approximately 250,000 acre-feet of usable groundwater. The groundwater basin provides the community with a local "water savings account," which serves as a hedge against a prolonged dry period or a temporary inability to import surface water. In the event of a prolonged drought, this amount of water is enough to sustain the entire Tri-Valley for up to six years, depending on the amount of surface water available and the conservation efforts of water users.

Management of the groundwater basin is a complex task requiring consideration of water supply, water quality and other issues. Zone 7 has prepared a number of planning documents and implemented a number of management plans to address management of the groundwater basin, including a Groundwater Management Plan, Well Master Plan and a Salt Management Plan. Each of these plans has specific objectives related to providing Zone 7's customers with a high quality, reliable water supply. In the future, Zone 7 will be further evaluating what role the Chain-of-Lakes facilities will play in water supply, groundwater management and flood control, and the Zone will also need to carefully evaluate the potential impacts of climate change on all of these plans, to ensure continued effective management of the available water resources and groundwater basin.

Groundwater Recharge Operations

The groundwater basin underlying the Tri-Valley area is naturally refilled, or "recharged", from stream flow, subsurface inflows, rainfall and applied irrigation water seeping into the ground. Zone 7's groundwater management program ensures that water levels within the basin will be maintained at acceptable levels. However, if climate change occurs, rainfall amounts and the timing and amount of stream flows may be impacted, potentially impacting the amount of water available to both naturally and artificially recharge the groundwater basin.

In addition to natural recharge, Zone 7 manages an artificial recharge program. During spring, summer and fall when the streams are typically dry, Zone 7 releases some of its purchased imported water into the Arroyo del Valle and Arroyo Mocho. By allowing the water to flow through sections of these arroyos where the creek bottoms are very porous, the water quickly seeps into the ground, replenishing the groundwater basin.

Zone 7's operational policy is to maintain the balance between the combination of natural and artificial recharge and withdrawal. By artificially refilling or recharging the groundwater basin, and monitoring water levels throughout the valley, Zone 7 ensures that the water demands of the community are met. However, if rainfall and stream flows are reduced due to climate change, and available imported supplies become limited, less water will be available to naturally and artificially recharge the groundwater basin.

"Chain-of-Lakes" Operations

In 2003, Zone 7 began operation of the first phase of the "Chain-of-Lakes" Project, a series of reclaimed gravel quarries to be used for seasonal water storage and conveyance and potentially, in the future, flood water detention and conveyance. In 2003, Lakes H and I were converted to capture, store and recharge water available during wet and/or normal years, thereby increasing annual groundwater replenishment capability. Additional lakes in the "Chain-of-Lakes" will become available to Zone 7 in the future to expand this program. Planning for future expansion of the "Chain-of-Lakes" will need to consider the potential impacts of climate change on available water supplies and the potential need for additional flood control, sedimentation and detention facilities.

LAKE DEL VALLE OPERATIONS

A portion of Zone 7's water supply comes from runoff in the local watershed that flows into the Lake del Valle Reservoir from the surrounding hills and valleys, where it is stored for later use. As discussed in Section 3, reservoir operations could be impacted by future climate change as additional flood control space may be required to handle more intense rainfall and shifts in precipitation patterns. These changes may make it more difficult to refill reservoir flood control space during late spring and early summer, potentially reducing the amount of surface water available during the dry season.

FLOOD CONTROL

To water supply operations, Zone 7 currently owns and maintains about 39 miles of local flood control channels in the Tri-Valley, which is about one-third of all of the Valley's channel and creeks. When the flood control system within Zone 7's service area is complete, the agency could own and maintain as many as 120 miles of creeks and channels. As discussed in Section 3, climate change impacts may include more intense rainfall events and shifts in precipitation patterns, which may increase the frequency and severity of local flood events.

In order to minimize the impacts of such events, Zone 7's Flood Control Section manages a comprehensive maintenance program that ensures that its channels are ready for large storms. This includes such routine maintenance activities as inspections, embankment and drain structure repairs, vegetation management, silt removal, and pest control. Also, Zone 7's Flood Control Section administers an emergency response program that prepares Zone 7 to respond to emergency situations and minimize the loss of life and property should a flood occur.

SECTION 6. WATER MANAGEMENT OPTIONS TO ADDRESS CLIMATE CHANGE AND ITS IMPACTS

Irrespective of cause or possible severity, climate change is here and water resource managers need to plan for potential impacts as part of their future programs. Impacts to water supply reliability are specific to individual water systems, since some are more directly dependent on annual climate conditions than others. Climate change also needs to be taken in context with other uncertainties faced by water resource managers, including the uncertainty of future population increases in their service areas.

These factors were discussed at the September 2005 conference "Urban Water Supplies and Climate Change in the West". DWR Director Lester Snow ended his presentation at this conference with the following recommended water resource actions to cope with climate change:

- Increased monitoring of climatologic and water resource conditions
- Re-regulation of surface reservoirs (i.e., re-designating a portion of the available storage for flood control storage space)
- Increased water use efficiency
- Construction of additional on-stream and/or off-stream reservoirs
- Increased groundwater recharge/conjunctive management
- Increased water banking and transfers
- Construction and operation of new/alternate water conveyance facilities
- Delta levee augmentation/rehabilitation
- Delta/Suisun Marsh modification
- Crop shifts/fallowing
- Water right revisions--amount/timing/location of diversions (SWRCB)
- Increased enforcement actions against illegal diversions (SWRCB)
- Nutrient control and other measures to protect water quality
- Installation of additional cold-water release facilities from reservoirs
- Shoreline engineering to protect coastal resources, including coastal aquifers
- Implement changes in aquatic habitat restoration efforts
- Observe and react

Despite individual circumstances, a subset of DWR Director Snow's recommendations makes sense for most California water utilities:

- Consider re-regulation of surface water reservoirs (i.e., re-designation of a portion of the available storage for flood control storage space),
- Diversify supplies as much as possible, especially in the areas of water transfers, groundwater banking, and conjunctive use, and
- Increase the efficient use of all supplies through conservation and reuse.

For those, like Zone 7, that are very reliant on Delta supplies, it is essential to secure adequate storage at the local level, develop emergency contingency plans with adjacent water utilities, and keep engaged in the debate over the risks and possible solutions to catastrophic failure of the Delta as a water supply source. In particular, it is recommended that the following actions be considered to be better prepared in the event of a possible catastrophic failure of the Delta:

- Adopt a policy statement that recognizes the importance of the Delta (from both a water quantity and water quality standpoint), to the Zone's Integrated Water Resources Plan, and continue to work with other agencies to develop and implement a solution,
- Continue to evaluate and develop additional local storage opportunities,
- Continue to explore and develop emergency supply plans with other adjacent water agencies, and
- Apply for additional local water rights to allow for diversion and use of local watershed runoff during high flow periods.

With respect to Item 1 above, in July 2006, Zone 7 adopted a resolution adopting several policy principles for the preservation of a healthy Bay-Delta ecosystem that continues to support water quality and reliability needs in the State of California[65]. Some of the key points of the resolution included the following:

- The Zone 7 Board of Directors urge the Governor to continue to support actions and equitable financing plans that will provide for long-term sustainability of the Delta, and assure that California is prepared for and can respond to a possible catastrophic event in the region.
- The Zone 7 Board of Directors support the development of science-based regional conservation plans in the Delta and in watersheds that drain through the Sacramento and San Joaquin Rivers and their tributaries to the San Francisco Bay-Delta as a way to obtain regulatory assurance, long-term funding, and to implement a comprehensive, long-term program for the restoration and maintenance of the Bay-Delta ecosystem and fisheries.
- The Zone 7 Board of Directors are committed to providing their fair share of funding that would be required to implement an effective conservation plan, and be dedicated solely to the restoration and maintenance of the Bay-Delta ecosystem.

- The Zone 7 Board of Directors are committed to working with all other parties in a voluntary process to develop appropriate conservation plans adequately supported by a long-term fair share funding program for the purpose of Bay-Delta ecosystem restoration and maintenance.
- The Zone 7 Board of Directors support the development of strong working relationships with the State and Federal regulatory agencies that manage or plan ecosystem restoration and maintenance programs or projects in the Delta.
- Zone 7 is committed to maximizing available and reasonable cost-effective alternative sources of water to meet new regional demands before consideration of additional supplies from the Bay-Delta; and will refrain from seeking additional supplies from the Bay-Delta unless it can be reasonably demonstrated that no other alternatives are reasonably available and that such additional exports will not cause harm to the Bay-Delta ecosystem.

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