CHAPTER 5

Climate Change

5.1 Introduction

5.1.1 Chapter Overview

This chapter presents a discussion of climate change – what it is and its potential environmental consequences as understood to date – with a focus on climate change issues that are relevant to the Los Vaqueros Reservoir Expansion Project. Two general areas of inquiry are the focus of this discussion:

- To what extent would the project contribute to the global greenhouse gas (GHG) emissions that are causing climate change?
- Would the project be adversely affected by the environmental changes projected to result from climate change and/or would the project contribute to the adverse effects of climate change?

Whether the project will contribute to GHG emissions is an air quality issue and, therefore, is analyzed in Section 4.10, Air Quality, of this Environmental Impact Statement/Environmental Impact Report (EIS/EIR). The second area of inquiry, the extent to which the project affects or is affected by the projected environmental consequences of climate change, centers on potential changes to water resources, water supply, and water quality.

5.1.2 Overview of Climate Change

Various gases in the earth's atmosphere, classified as atmospheric GHGs, play a critical role in determining the earth's surface temperature. Solar radiation enters earth's atmosphere from space, and a portion of the radiation is absorbed by the earth's surface. The earth emits this radiation back toward space, but the properties of the radiation change from high-frequency solar radiation to lower-frequency infrared radiation. GHGs are transparent to solar radiation and, therefore, are effective in absorbing infrared radiation. As a result, radiation that otherwise would escape back into space is retained, resulting in a warming of the earth's atmosphere. This phenomenon is known as the GHG effect.

Scientific research to date indicates that observed climate change is most likely a result of increased emission of GHGs associated with human activity (Intergovernmental Panel in Climate Change, 2007a, 2007b). Among the prominent GHGs contributing to the greenhouse effect are carbon dioxide (CO_2), methane (CH_4), ozone (O_3), water vapor, nitrous oxide (NO_x), and chlorofluorocarbons (CFCs). Human-caused emissions of these GHGs in excess of natural ambient concentrations are responsible for enhancing the greenhouse effect. GHG emissions contributing to global climate change are attributable in large part to human activities associated with the industrial/manufacturing, utility, transportation, residential and agricultural sectors (CEC, 2006). In California, the transportation sector is the largest emitter of GHGs (accounting for 40.7 percent of the total GHG emissions in the state in 2004), followed by electricity generation (CEC, 2006).

As the name indicates, global climate change is a global problem. GHGs are global pollutants, unlike criteria air contaminants and toxic air contaminants, which are pollutants of regional and local concern, respectively. If California were a country, it would rank between the 12th and 16th largest emitter of CO2 in the world. California produced 492 million gross metric tons of carbon dioxide equivalents[1] in 2004 (CEC, 2006).

California is taking actions to reduce GHG emissions. Governor Schwarzenegger signed Executive Order S-3-05 in June 2005 to address climate change and GHG emissions in California. This order sets the goal that GHG emissions be reduced as follows:

- To 2000 levels by 2010
- To 1990 levels by 2020, and
- To 80 percent below 1990 levels by 2050

In 2006, California passed the California Global Warming Solutions Act of 2006 (AB 32; California Health and Safety Code Division 25.5, Sections 38500, et seq.). This Act requires the California Air Resources Board (CARB) to design and implement emission limits, regulations, and other feasible, cost-effective measures to reduce statewide GHG emissions to 1990 levels by 2020 (representing an approximate 25 percent reduction in emissions).

Global climate change will affect water resources in California. Rising temperatures will result in sea-level rise and perhaps the timing and amount of precipitation, which, in turn, could alter water quality. Climate change is also expected to result in more extreme weather, both heavier precipitation that can lead to flooding as well as more extended drought periods. Although much uncertainty remains regarding the timing, magnitude, and nature of potential changes to water resources as a result of climate change, several trends are evident. Thus, it is valuable to evaluate projects such as the Los Vaqueros Reservoir Expansion Project in light of these potential changes in water resource conditions.

1 Carbon dioxide equivalents (CO_2E) are measurements used to account for the fact that different GHGs have different potential to retain infrared radiation in the atmosphere and contribute to the greenhouse effect. This potential, known as the global warming potential of a GHG, is also dependent on the lifetime, or persistence, of the gas molecule in the atmosphere. For example, methane is a much more potent GHG than CO_2. As described in the General Reporting Protocol of the California Climate Action Registry, one ton of CH_4/methane contributes as much to the greenhouse effect as approximately 21 tons of CO_2/carbon dioxide (California Climate Action Registry, 2006). Expressing all GHG emissions in carbon dioxide equivalents converts them to a common unit of measurement calculated as if only CO_2 were being emitted.

5.2 Potential Changes to California's Water Resources

Focusing on precipitation, snow pack, runoff, flooding, and sea-level rise, the following text describes the potential for climate change to affect California's water resources.

5.2.1 Precipitation, Snowpack, and Runoff

Amount of Precipitation

Most precipitation events in California occur during the October through April rainy season with the largest amount of water falling during November through March. An analysis by the U.S. National Weather Service (USNWS) using data from 1931 through 2005 indicates a long-term trend of increasing annual precipitation in California, especially in northern California, where data show an increase of up to 1.5 inches per decade (USNWS, 2008). A second investigation completed by the California Department of Water Resources (DWR) indicates a statistically significant trend towards increased total precipitation in northern and central California since the late 1960s (DWR, 2006). A single investigation by Bardini and others (Bardini, et al., 2001) shows a trend of potentially decreasing annual precipitation in California; however, this result is probably related to the specific subset of data that the Bardini study relied upon, wherein extremes at the beginning or end of time series data can substantially impact the identified trend (DWR, 2006). An investigation of rainfall during November through March of 1930 through 1997 indicates significant increases in California rainfall (distinct from snowfall) (Mote, 2005).

There is also evidence that the amount of precipitation that occurs on an annual basis is becoming more variable. That is, periods of both high and low rainfall are becoming more common. Specifically, a study performed by DWR indicates that present-day variability in annual precipitation is about 75 percent greater than that of the early 20th century (DWR, 2006). The effects of these trends on the project along with trends resulting from climate change scenarios are discussed in the following subsections.

Snowpack and Snowmelt

In addition to potentially increased precipitation, snowpack and snowmelt may also be substantially affected by climate change. Because much of California's precipitation falls as snow in the Sierra Nevada and southern Cascades, the state's snowpack represents a significant reservoir of usable water. Specifically, about 35 percent of the state's usable annual surface water supply is derived from the annual snowmelt (DWR, 2006). This snowmelt typically occurs from April through July, providing natural water flow to streams and reservoirs after the annual rainy season has ended. Estimates by DWR further indicate that California's snowpack contributes, on average, about 14 million acre feet (MAF) per year of runoff to watersheds that flow into the Central Valley and Delta (DWR, 2006). For comparison, total reservoir capacity in the Central Valley is about 24.5 MAF per year (DWR, 2005a).

As air temperatures increase due to climate change, the water stored in California's snowpack could be affected in two ways: first, increasing temperatures could result in decreased snowfall, and second, increasing temperatures could result in earlier snowmelt. Several investigations of current and potential future snowfall trends in California illustrate these effects. Knowles and Cayan performed a model analysis of the portion of the California snowpack that feeds Delta watersheds. The study estimates that, by 2060, California's snowpack will be reduced substantially, especially within northern and eastern areas of the Sacramento River watershed (Knowles and Cayan, 2004). A recent study by the Scripps Institute of Oceanography estimates trends in snowpack, river runoff, and air temperatures in California and Oregon. Consistent with other studies, this investigation also indicates a substantial reduction in snowpack in California concurrent with an increase in winter rainfall (Scripps Institute of Oceanography, 2007).

Runoff

Runoff may be considered in terms of annual or peak runoff volumes. Annual runoff is measured during the annual water year (October 1st through September 30th) and includes river flows derived from precipitation events, snowmelt, and river base flow. Peak runoff is typically measured for individual storm events. Like annual runoff, peak runoff results from precipitation events, snowmelt, and river base flow. However, most of the water mass present during a peak runoff event is typically derived from concurrent precipitation and snowmelt.

As discussed above, precipitation across California appears to have increased over the past century, and the amount of precipitation that occurs in individual water years has become more variable. It follows, then, that similar trends would be seen for runoff. A study by DWR compares pre- and post-1955 annual average water year unimpaired runoff[2] for 24 watersheds across northern, central, and southern California (DWR, 2006). Data indicate an annual increase in runoff of up to 27 percent for 21 of the 24 watersheds, with an overall average increase of 9 percent. The remaining three watersheds – the Mokelumne, Stanislaus, and American Rivers – show runoff reductions of 1 to 2 percent.

The DWR study also addresses the amount of variability in runoff volumes among water years for the Sacramento and San Joaquin River watersheds. Results indicate a statistically significant increase in variability within the Sacramento River watershed, and an insignificant but increasing trend within the San Joaquin River watershed. Thus, the annual amount of runoff in the Sacramento River is becoming increasingly variable, and annual runoff in the San Joaquin may follow a similar trend (DWR, 2006).

In relation to snowpack, winter storms produce snow to higher elevations than other storms, snow that has historically melted during April through July. This process effectively stores water in California's snowpack until the spring snowmelt when the water flows downstream into major rivers and reservoirs, providing a significant portion of the water supply for the dry summer and autumn. April through July runoff in both the Sacramento and San Joaquin Rivers shows a

2 Unimpaired runoff refers to the runoff water that occurs within a river above major regulating impoundments (e.g., major dams).

decreasing trend over the last century, indicating that, in both watersheds, an increasing percentage of runoff is occurring earlier in the year when many reservoirs are managed primarily for flood control and not for water supply (DWR, 2006).

These changes in the timing of precipitation and runoff, and in the amount of water stored in California's snowpack, have significant implications for the management of water resources in the state. These effects are discussed in greater detail below.

5.2.2 Flooding and Flood Management

As discussed above, it is anticipated that climate change will have a substantial effect on the timing and magnitude of snowfall, rainfall, and snowmelt events in California. Large annual variations in winter rainfall and runoff, which are normal in California, create uncertainty about climate change's potential to affect flooding. Still, based on more than a century of historical data and global and local-scale climate modeling efforts, a few generalities have emerged.

In terms of flooding, a peak flow analysis of three Delta tributaries was completed (DWR, 2006). The Feather, American, and Tuolumne Rivers were selected for their century-long, 3-day peak flow records. The investigation divided in half a century-long dataset to compare pre-1955 to post-1955 data. Results indicated that the 100-year 3-day peak flows have more than doubled in the American (111 percent increase) and Tuolumne (102 percent increase) Rivers, and increased by 51 percent in the Feather River. Comparing the pre- to post-1955 periods, only one major flood event occurred prior to 1955 in the three rivers, while four occurred during the post-1955 period. Thus, annual peak 3-day mean discharges in Central Valley watersheds are becoming larger and more variable. Independent climate modeling efforts (Dettinger, et al., 2004; Miller, et al., 2003), predict that these trends towards more variable river flows and more frequent flooding events will continue as a result of climate change.

5.2.3 Sea-level Rise

According to DWR, mean sea level at the Golden Gate Bridge has risen by at least 8 inches since 1900 (DWR, 2006). This corroborates a report by the Intergovernmental Panel on Climate Change (IPCC), which indicates average increases of 3.9 to 7.9 inches globally during the last century (IPCC, 2007a). The observed sea-level rise likely results from a combination of factors, including melting of polar and terrestrial ice and snow, and thermal expansion of ocean water as the earth's temperature has increased (IPCC, 2007b).

Efforts have also been made to predict the amount of sea-level rise likely to occur in the future under various worldwide GHG emissions scenarios. A 2007 IPCC report provides estimates of potential sea-level rise over the next century. That study indicates that global sea level could increase by an estimated 7 to 23 inches by 2099, or about 0.6 to 3.8 inches per 10 years (IPCC, 2007b). There is some disagreement and uncertainty about sea-level rise projections (Munk, 2002); however, the 2007 IPCC report is probably the most highly regarded study on the subject.

5.2.4 Implications for Los Vaqueros Reservoir Expansion Project

The project's expanded Old River Intake and Pump Station and the new Delta Intake and Pump Station would be in the Delta along Old River. This area would potentially be subject to increased flow of water from upstream areas as a result of flooding in the watershed's tributary to the Delta. These increased flood flows, in combination with sea-level rise discussed above that could occur as a result of climate change, could result in increased frequency of high water within the Delta.

However, the new Delta Intake and Pump Station would be designed to withstand projected high-water flood flows. Design of existing and future facilities incorporates the likelihood of high water levels increasing by over 3 feet; should water levels rise even higher, the facilities could be modified to accommodate them. Neither the expanded Old River Intake and Pump Station nor the new intake structure would significantly impede or redirect flood flows through the Delta because neither protrudes significantly into existing channels.

As discussed above, climate change could increase the frequency or severity of flooding within California. The Kellogg Creek watershed, as well as other minor tributaries to the Los Vaqueros Reservoir, could therefore receive increased flood flows during storm events, and these local storm flows would be collected in the expanded Los Vaqueros Reservoir. As discussed in Section 4.5, Local Hydrology, Drainage, and Groundwater the existing Los Vaqueros reservoir is sized and designed appropriately to either contain flood flows from Kellogg Creek and other minor tributaries to the reservoir, or release those flows downstream.

While the Los Vaqueros Reservoir is designed to function primarily as a water storage facility, expansion of the existing reservoir would provide additional capacity to withhold increases in future flood flows within the Kellogg Creek watershed. Under dam safety regulations, just as the existing reservoir has adequate water storage above its maximum levels to contain and hold the probable maximum flood, the expanded reservoir would also be required to have such capacity. Should future studies indicate a larger flood is probable as a result of climate change, the reservoir operations in winter would be adjusted to retain larger flood flows.

Setback levees surrounding the pump stations are designed and engineered to modern standards and incorporate features that make them far less likely to fail than typical Delta levees. Consequently, flooding caused by failure of levees on Byron Tract or Victoria Island is unlikely to affect the pump stations. Pipelines on islands and tracts subject to flooding are designed to allow access for maintenance, should that be necessary, under flood conditions on the islands. Both Byron Tract and Victoria Island house infrastructure of statewide importance and, in the case of Byron Tract, include a significant number of inhabitants. Consequently, neither Byron Tract nor Victoria Island is likely to be abandoned should it flood.

The expanded Old River Intake and Pump Station and the proposed new Delta Intake and Pump Station would be along Old River in an area that would potentially be subject to a projected climate-induced sea-level rise of about 1 to 3 feet (DWR, 2006). Intake facilities would be designed to withstand inundation and be installed at a height above the potential inundation level. Sea-level rise would not be expected to have a significant effect on the proposed intake and pumping facilities. During the project design phase, project engineers will address the most current information regarding potential sea-level rise and will design pumps and other infrastructure to endure higher flood levels.

Portions of the Delta-Transfer Pipeline would lie within areas that are presently in the 100-year flood zone, as shown on Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRM). These areas would be potentially subject to additional Delta flooding associated with a rise in sea level. However, the Delta-Transfer Pipeline would be buried underground, so that flooding, if it did occur, would not disturb, obstruct, or otherwise damage the pipeline. The Transfer-LV Pipeline alignment would reach elevations above 150 mean sea level (msl) and, therefore, would not be in the portion of the project area potentially affected by sea-level rise or associated flooding.

The potential effects of sea-level rise on Delta water quality are discussed in subsection 5.3.2.

5.3 Potential Effects on Water Supply and Water Resources Management

The following text discusses existing climate change research and the potential for climate-induced effects to alter water management within California's natural and managed water environment.

5.3.1 Effects on the State Water Project and Central Valley Project

Reports by the U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region (Reclamation) and DWR, prepared in response to Executive Order S-3-05, represent the latest complete analysis of changes to State Water Project (SWP) and Central Valley Project (CVP) operations that are likely to occur as a result of climate change. Reclamation prepared *Sensitivity of Future Central Valley Project and State Water Project Operations to Potential Climate Change and Associated Sea Level Rise,* Appendix R of the *Operations and Criteria Plan (OCAP) Biological Assessment* (Reclamation, 2008). DWR wrote the Technical Memorandum Report *Progress on Incorporating Climate Change into Management of California's Water Resources* (DWR, 2006) and *The State Water Project Delivery Reliability Report, 2007* (DWR, 2008).

Contained in these reports is an analysis of the potential impacts of climate change on SWP and CVP operations and deliveries, as well as on Delta water quality and water levels. The analysis is based on runs of the CalSim II and DSM2 models, which are described in more detail in Section 4.2, Delta Hydrology and Water Quality. The specific CalSim II and DSM2 methodology used for the climate change analysis is detailed in the first-mentioned DWR report (DWR, 2006).

Results discussed in the reports include projections from 2035 through 2064 in four potential climate change scenarios compared to a base case scenario that does not assume climate change effects. The four potential climate change scenarios were based on modeling output from two separate global climate models (**Table 5-1**). Three of these scenarios presumed decreased average annual precipitation, while one assumed increased average annual precipitation. Results from the investigations are considered preliminary, incorporate several assumptions regarding the effects of climate change on California water resources, and reflect a limited number of climate change scenarios.

TABLE 5-1
PRECIPITATION PROJECTIONS FOR THE FOUR CONSIDERED CLIMATE CHANGE SCENARIOS

	Average Change in Precipitation (in/yr)	
Climate Scenario[a]	**Northern California**	**Southern California**
2050 GFDL A2	-0.75	-0.22
2050 PCM A2	-0.25	-1.77
2050 GFDL B1	-0.62	0.7
2050 PCM B1	0.83	-0.08

[a] The four climate scenarios DWR investigated were chosen from among several available scenarios compiled for the United Nations' Intergovernmental Panel in Climate Change's (IPCC's) Fourth Assessment Report. The four climate changes scenarios consist of two GHG emissions scenarios, A2 and B1. Each of the GHG emissions scenarios is represented by two different Global Climate Models, the Geophysical Fluid Dynamic Lab model (GFDL) and the Parallel Climate Model (PCM). Climate scenarios were modeled on a 2050 timeframe.

SOURCE: DWR, 2006

Results from the four modeled scenarios indicate effects to SWP and CVP operations. Because of shifts in seasonal and annual average runoff, the amount of water delivered by the SWP and CVP was reduced considerably. Under three of the four climate change scenarios, reservoir water levels were drawn to the minimum level (dead storage) during 21 to 31 months for Shasta, and 20 to 28 months for Folsom during the period of record, as compared to 1 month for each reservoir under a scenario without climate change. During these months, streamflow requirements were not predicted to be met on the Sacramento and American Rivers, and the CVP would not be able to contribute to its Coordinated Operation Agreement-defined share of in-basin use. However, it is thought that these are modeling artifacts; DWR suggests that these results would be avoided by making carryover storage allocations more conservative within the CalSim II model. Still, the overall projected trend shows a decrease in water availability within the system (DWR, 2006).

SWP Deliveries

As discussed above, climate change would generally increase the amount of runoff that occurs during winter and early spring and reduce the amount of runoff during late spring and early summer. Results from the DWR investigations show that these changes would make it more difficult to capture water in SWP and CVP facilities for delivery later in the year. Specifically, average annual deliveries to contractors could be reduced by 7 to 10 percent under three of the four scenarios, and increased by 1 percent under the remaining scenario. In general, drought-year only deliveries could also be reduced for three of the four scenarios, in comparison to the base case. Reclamation studies (Reclamation, 2008) that included both sea-level rise and four climate scenarios arrived at generally the same conclusions: depending on the scenario, changes in SWP deliveries could range from +7 percent (wetter scenarios) to -15 percent (drier scenarios).

SWP Carryover Storage

Carryover storage is defined as the volume of water that remains in a given reservoir after all annual deliveries and releases have been fulfilled. Carryover storage can then be used during the following water year to supplement water supply in case of drought. DWR analyzed SWP carryover storage as the sum of Oroville and SWP storage in San Luis Reservoir on September 30th, a date that coincides with the end of the water year. Results indicate that carryover storage would be consistently lower under three of the four climate change scenarios, with reductions of about 10 percent at the 90 percent exceedance probability level,[3] to reductions of up to 28 percent at the 10 percent exceedance probability level. Results for the remaining fourth scenario indicate slightly increased carryover storage during below normal, dry, and critical water years, and slightly decreased carryover storage during above normal and wet water years (DWR, 2006).

CVP South of Delta Deliveries

Deliveries by the CVP to South of Delta (SOD) contractors were also affected under each of the four climate change scenarios. Under the three drier scenarios, DWR found that annual average CVP SOD deliveries would be reduced by 6 to 10 percent, likely resulting from generally drier conditions and a shift towards reduced April-July runoff and increased winter season runoff under these scenarios (DWR, 2006). The wetter scenario still exhibited increased winter season runoff and decreased April-July runoff but resulted in a 3 percent average annual increase in CVP SOD deliveries. Reclamation studies that included both sea-level rise and four climate scenarios came to generally the same conclusions: depending on the scenario, changes in CVP deliveries could range from +4 percent (wetter scenarios) to -12 percent (drier scenarios) (Reclamation, 2008).

CVP Carryover Storage

DWR found that changes in CVP carryover storage, defined as the sum of Trinity, Shasta, Folsom, and CVP storage in San Luis Reservoir on September 30th, would be similar to those described for SWP carryover storage. Specifically, results indicate that carryover storage would be consistently lower under three of the four climate change scenarios, with reductions of about 26 to 47 percent at the 90 percent exceedance probability level, and reductions of 4 to 15 percent at the 10 percent exceedance probability level. The fourth, wetter climate change scenario resulted in an increase of 9 percent at the 90 percent exceedance probability level, and a

3 Exceedance probability for carryover storage is the percent chance of surpassing a specific volume of remaining carryover storage. For instance, under the base case scenario modeled by DWR (2006), there is a 90 percent chance that carryover storage during a given year will exceed 1,300,000 acre feet (AF). This means that the probability of exceedance for 1,300,000 AF of carryover storage is 90 percent, and only during 10 percent of years (the driest years) would there be less than 1,300,000 AF of carryover storage.

slight reduction of less than 1 percent at the 10 percent exceedance probability level (DWR, 2006). Reclamation studies indicate a similar range of carryover storage (Reclamation, 2008).

5.3.2 Effects on the Delta

Making use of CalSim II and DSM2 modeling exercises, DWR also analyzed the potential effects of climate change on the Delta. Details regarding this modeling analysis and underlying assumptions for the CalSim II and DSM2 models can be found in the DWR report (DWR, 2006).

Delta Inflow and Delta Outflow

Delta inflow is defined as the volume of water that flows into the Delta from a combination of the Sacramento, San Joaquin, and east-side Rivers. Delta inflow is important to Delta operations since, during dry summer and autumn periods, Delta water quality and flows must be sustained by either reducing Delta exports or increasing upstream releases. Additionally, the permitted pumping capacity at the SWP Banks Pumping Plant depends on inflow to the Delta from the San Joaquin River, from December 15th through March 15th. Under the three drier climate change scenarios, annual average Delta inflow would decrease by 3 to 4 percent in comparison to the base case scenario. Under the wetter climate change scenario, annual average Delta inflow would increase by 5 percent.

Considered on a monthly basis, average Delta inflow under all four climate change scenarios would increase, relative to the base case scenario, during December through March. This increase corresponds to increased rain and decreased snow events during this period, which results in additional flood control releases from upstream reservoirs and, therefore, greater Delta inflow. Conversely, under the three drier climate change scenarios, inflows from the Sacramento River to the Delta would decrease overall in comparison to the base case.

Delta outflow is defined as the volume of water that exits the Delta via the San Francisco Bay. Delta outflow helps maintain acceptable salinity levels within the Delta, facilitating pumping at state, federal, and local water project pumps, as well as maintaining Delta water quality. Under the three drier scenarios, CalSim II modeling indicates that there would be no reduction in required Delta outflow, but that there would be a 0 to 4 percent reduction in total Delta outflow (including surplus Delta outflow). The wetter climate change scenario would result in an overall increase in total Delta outflow of about 6 percent.

Delta Exports

Exports from the Banks and Tracy Pumping Plants and into the SWP and CVP, respectively, are considered together in DWR's CalSim II analysis of Delta exports. The modeling results indicate that total average annual changes in Delta exports to the two water systems combined would be reduced by 6 to 10 percent for the three drier climate change scenarios, and would increase by 2 percent under the wetter climate change scenario. On a monthly basis, average winter month exports under all four climate change scenarios would not be significantly changed, as compared to the base case scenario. Conversely, during July through November, monthly average Delta exports would be reduced by up to about 20 percent for the three drier climate change scenarios. During most non-winter months, the wetter climate change scenario would not result in any substantial differences from the base case scenario.

DWR has updated its 2006 water supply reliability studies and has included current fishery restrictions on export pumping that were previously excluded. This latest modeling included moderate and severe fishery restrictions and several future climate model scenarios. The results of the updated modeling show that future climate conditions would have a smaller effect on operations than the previous studies indicated. Namely, depending on the climate scenario, average deliveries under future conditions would be slightly higher or about the same as those under current conditions. Overall, anticipated deliveries were reduced compared to the 2005 studies for both current and future conditions, largely due to the increased fishery restrictions (DWR, 2008). The results of the 2008 update are consistent with the studies used for the analysis of the project provided in this Draft EIS/EIR.

Sea-level Rise and Delta Water Quality

The greatest effect of sea-level rise on California's water supply would most likely occur in the Delta (DWR, 2005b). Specifically, rising sea levels in the vicinity of below-sea-level Delta islands would place additional stress and pressure on the Delta's existing levee system, potentially leading to more frequent overtopping and levee failures. Additionally, higher sea levels would push saltwater up into the Delta, potentially degrading freshwater quality at state, federal, agricultural, and local municipal pumping facilities. To offset increased salinity intrusion, Delta pumping could be curtailed, or upstream reservoir releases could be increased.

DWR conducted a preliminary modeling effort to evaluate potential impacts on Delta water quality. The DSM2 modeling study investigated how a 1-foot rise in sea level would affect Delta water quality. The model did not account for potential CVP or SWP operational changes. Results show an increase in salinity within the Delta under the 1-foot rise scenario, although this change is attributed largely to an assumed increase in the tidal range, not the overall mean sea-level rise (DWR, 2006). Whether or not to anticipate an increase in tidal range with sea-level rise is under further investigation. Still, chloride concentrations along Old River at Rock Slough were assumed to be below the 250 mg/L threshold during about 90 percent of the modeled period.

Under real-time conditions, releasing additional water from SWP and CVP reservoirs would offset increases in Delta salinity. Thus, water quality standards would be met but, during those times when additional water releases were not necessary to meet a standard, water quality would be degraded incrementally as a result of seawater intrusion. This, in turn, would incrementally degrade Delta water quality for drinking water purposes. Increasing reservoir releases to maintain Delta water quality could also affect supply reliability.

Sea-level Rise and Levee Overtopping

The DWR investigation included a preliminary analysis of the potential for levee overtopping under a scenario of a 1-foot increase in sea level. Three Delta islands – Sherman Island, Twitchell Island, and Jersey Island – were specifically considered in the analysis. These islands were selected due to their proximity to the ocean and vulnerability to overtopping should the sea level rise. Results of the DSM2 model, with its assumption of a 1-foot sea-level rise, show an increase in potential overtopping events from zero under the simulated base case scenario to two at a series of five low points along the levees of the Delta islands considered (DWR, 2006).

The model does not account for increased variability of inflows to the Delta from upstream sources or for the effects of wave action. However, both overtopping events occurred in the model during historically high water levels. Flooding of the islands could result in significant seawater intrusion if it occurs in dry periods, possibly making Delta water undrinkable for an extended period of time. If the levees were to be abandoned and not repaired, the resulting increase in surface water in the western Delta would result in permanent increased salinity intrusion. By contrast, permanently flooding interior islands would reduce seawater intrusion on a permanent basis.

Adaptive Management Approaches

Current research generally indicates that the most probable impacts of climate change on water resources would be related to increased peak winter flows and decreased spring and early summer runoff. As discussed above, these changes in water flow would result in less water available for capture through the CVP and SWP, as well as through other local water projects and diversions. Without substantial changes in water management, it is, therefore, likely that climate change could lead to reduced deliveries to water contractors north and south of the Delta who rely on water supplies from the SWP, the CVP, and local sources.

Climate change most likely would reduce spring and early summer snowmelt, while increasing water discharged during winter months, from the standpoint of water supply, it would be useful to have additional screened, winter pumping capacity in the Delta. Such additional pumping capacity would facilitate retention and storage of storm season flood flows. Accordingly, DWR concluded that the key constraint to increasing winter withdrawals of Delta water is permitted and physical capacity at the Banks Pumping Plant for the SWP (DWR, 2006). CVP exports from the Tracy Pumping Plant have often been limited by the upper Delta Mendota Canal constriction, although the California Aqueduct-Delta Mendota Canal intertie could potentially be used to provide additional water supply from the SWP's California Aqueduct to the CVP's Delta Mendota Canal.

Additional permitted or physical, screened pumping plant capacity, along with supplemental SWP SOD conveyance capacity (surface storage, canals, pumps, and groundwater banking) and changes in management of the California Aqueduct-Delta Mendota Canal intertie, would potentially alleviate the reduced water supply that would result from climate change. Increasing the ability of water managers to adaptively manage Delta withdrawals and SOD storage would permit more effective withdrawal, storage, and distribution of water resources while minimizing impacts to Delta aquatic habitat and sensitive species.

5.3.3 Los Vaqueros Reservoir Expansion Project

The project would provide several opportunities for management to be flexible and implement adaptive management strategies to improve water supply reliability. As described above, two of the primary factors that would constrain water managers' ability to maintain existing levels of water supply as a result of climate change are limited pumping and storage capacity. The project would help to alleviate both of these constraints.

Under Alternatives 1 and 2, the new Delta Intake and Pump Station would provide 170 cfs of additional screened diversion capacity from the Delta, and the existing Old River Intake and Pump Station and Alternative Intake Project on Victoria Canal (AIP) would be operated at a combined rate of 500 cfs (up from current operations of 320 cfs combined). Total pumping capacity under Alternatives 1 and 2 would be 670 cfs, an increase of 350 cfs over the capacity of current operations. Under Alternative 3, the pumping capacity of the Old River Intake and Pump Station would be expanded by 70 cfs, which, in combination with the AIP, would become 570 cfs (an increase of 250 cfs over the current 320 cfs combined capacity).

This supplemental diversion capacity would be useful during the increased winter runoff scenarios that are projected under the effects of climate change. The additional 175 TAF of storage capacity in Los Vaqueros Reservoir under Alternatives 1 through 3 would allow needed flexibility between the timing of diversion and the timing of use. The South Bay Aqueduct (SBA) Connection included in Alternatives 1 and 2 would also permit direct conveyance of water from the Los Vaqueros Reservoir or the associated Delta intakes to the SBA via Bethany Reservoir and the South Bay Pumping Plant. Alternative 4 would provide an additional 60 TAF of storage capacity.

The extra intake and storage capacity provided by Alternatives 1 through 3 would substantially increase the flexibility of water diversion and delivery operations that will be needed to sustain water supply reliability under the projected effects of climate change. Alternative 4 would increase flexibility to a lesser extent. The project would help mitigate the effects of climate change and would facilitate the use of water to benefit fish and other aspects of the environment. **Table 5-2** compares the additional water management flexibility, in terms of pumping and storage capacity, that would result from each of the project alternatives.

TABLE 5-2
SUMMARY OF ADDITIONAL WATER MANAGEMENT FLEXIBILITY TO MITIGATE CLIMATE CHANGE

Alternative	Increase in maximum diversion capacity (cfs)	Increase in reservoir storage capacity (TAF)	Environmental Water Flexibility	Water Supply Flexibility	SBA Connection
Alternative 1	350	175	yes	yes	yes
Alternative 2	350	175	yes	yes	yes
Alternative 3	250	175	yes	yes	no
Alternative 4	0	60	yes	yes	no

Operations of the Delta were also examined under future climate change conditions with and without an expanded Los Vaqueros Reservoir. As expected, the response to climate change is mixed, depending on the assumptions and models used. Generally, available water supplies would decrease in drier years and would be mixed in wetter years, reflecting wetter conditions but earlier runoff. Generally, water quality conditions would degrade somewhat, especially in drier years, but water quality standards would still be met.

Operations of an expanded Los Vaqueros Reservoir respond in the following ways to climate change scenarios:

- The reservoir storage would tend to be lower in drier periods because of degraded water quality and reduced water availability. This indicates that stored water would be used more frequently in drier periods. Modeling also indicates that a modest increase of about 150 cfs in intake capacity over the amount planned for the proposed project would more than offset this effect of reduced storage levels. Such additional intake capacity could be considered in the future if climate change leads to the drier scenarios.

- The reservoir would tend to be at higher levels in wetter scenarios because of improved water quality and increased winter flows.

None of the climate change scenarios examined indicate that conclusions about the expansion project's impacts should be altered. Similarly, conclusions of the latest DWR studies (DWR, 2008) show only very modest changes in SWP operations under climate change scenarios.