12. CLIMATE CHANGE

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12.1 INTRODUCTION

Global climate change is playing an increasingly important role in scientific and policy debates related to water management. The most consequential impacts of climate change on water resources in the United States are likely to occur in the mid-latitudes of the west, where the runoff cycle is largely determined by snow accumulation and subsequent melt patterns. It is well documented that the effects of warmer climates on the timing of runoff in these regions likely will shift a portion of spring and summer runoff to periods earlier in the year. Despite the high degree of regulation in many water supply systems throughout the western United States, the resultant effects of these shifts on runoff seasonality generally are considered to be undesirable, because the amount of water stored in snowpack can be substantial and, under normal (i.e., historical) conditions, this stored water is relied upon to augment low stream flows during the relatively dry summers.[1]

Developing evidence indicates global climate change will have a marked effect on water resources in California. More than 150 peer-reviewed scientific articles on climate and water issues in California have been published to date, with many more in preparation, addressing a range of considerations from proposed improvements in the downscaling of general circulation models to understanding how reservoir operations might be adapted to new conditions.[2] Rising temperatures and sea levels, and changes in hydrological systems are recognized as potential threats to California's economy, public health and environment. In addition to the need for better understanding of the potential implications associated with these changes, it also is recognized that more research is necessary to identify which systems are most vulnerable.[3]

Various gases in the Earth's atmosphere, classified as atmospheric greenhouse gases (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, which are transparent to solar radiation, are effective in absorbing infrared radiation. As a result, this radiation that otherwise would have escaped back into space is now retained, resulting in a warming of the atmosphere. This phenomenon is known as the greenhouse effect.

Among the prominent GHGs contributing to the greenhouse effect are carbon dioxide (CO_2), methane (CH_4), ozone (O_3), water vapor, nitrous oxide, and chlorofluorocarbons (CFCs). Human-caused emissions of these GHGs in excess of natural ambient concentrations are responsible for enhancing the greenhouse effect. Emissions of GHGs contributing to global climate change are attributable in large part to human activities associated with the industrial/manufacturing, utility, transportation, residential, and agricultural sectors.[4] In California, the transportation sector is the largest emitter of GHGs, followed by electricity generation.[5] A byproduct of fossil fuel combustion is CO_2. Methane, a highly potent GHG, results from offgassing associated with agricultural practices and landfills. Processes that absorb and accumulate CO_2, often called CO_2 "sinks," include uptake by vegetation and dissolution into the ocean.

As the name implies, global climate change is a global problem. GHGs are global pollutants, unlike criteria air pollutants and toxic air contaminants, which are pollutants of regional and local concern, respectively. If California were a country, it would rank as the 12th to 16th largest emitter of CO_2 in the world. California produced 492 million gross metric tons of carbon dioxide equivalents in 2004.[6] Carbon dioxide equivalents is a measurement 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, CH_4 is a much more potent GHG than CO_2. As described in the General Reporting Protocol of the California Climate Action Registry,[7] one ton of CH_4 has the same contribution to the greenhouse effect as approximately 21 tons of CO_2. Expressing GHG emissions in carbon dioxide equivalents takes the contribution of all GHG emissions to the greenhouse effect and converts them to a single unit equivalent to the effect that would occur if only CO_2 were being emitted. Consumption of fossil fuels in the transportation sector was the single largest source of California's GHG emissions in 2004, accounting for 40.7% of total GHG emissions in the state.[8] This category was followed by the electric power sector (including both in-state and out-of-state sources) (22.2%) and the industrial sector (20.5%).[9]

12.2 REGULATORY SETTING

While there are numerous regulations related to air quality and emission in California standards, several recent State regulations specifically address global climate change. A description of these regulations is presented.

12.2.1 Assembly Bill 1493

In 2002, then-Governor Gray Davis signed Assembly Bill (AB) 1493. AB 1493 requires that the California Air Resources Board (CARB) develop and adopt, by January 1, 2005, regulations that achieve "the maximum feasible reduction of GHGs emitted by passenger vehicles and light-duty truck and other vehicles determined by the CARB to be vehicles whose primary use is noncommercial personal transportation in the state."

12.2.2 Executive Order S-3-05

Governor Schwarzenegger of California signed Executive Order S-3-05 on June 1, 2005. The Order recognizes California's vulnerability to climate change, noting that increasing temperatures could potentially reduce snowpack in the Sierra Nevada, which serves as one of the State's primary sources of water. Additionally, according to the Order, climate change could influence human health, coastal habitats, microclimates, and agricultural yield. To address these potential impacts, the Order mandates GHG emission reduction targets. More specifically, by 2010, GHG emissions are expected to be reduced to 2000 levels; by 2020, emissions are expected to reach 1990 levels; and by 2050, emissions are expected to be 80 percent below 1990 levels. The Secretary of the State Environmental Protection Agency (Secretary) will oversee the reduction program targets and coordinate efforts to meet these provisions with numerous State agencies, such as the Resource Agency, which includes the California Department of Water Resources (Department). The Secretary will also provide biannual reports to the Governor and the State Legislature regarding: (1) progress toward meeting the GHG emissions targets; (2) the ongoing impacts of global warming in the State, including impacts to water supply and the environment; and (3) potential mitigation and adaptation plans to combat these impacts. In order to achieve the climate change emission targets, in June 2005, the

Secretary formed the Climate Action Team, which is comprised of administrators from numerous state agencies.

12.2.3 Assembly Bill 32 – California Global Warming Solutions Act

The California Global Warming Solutions Act of 2006 (AB 32) was signed into law on September 27, 2006. With the Governor's signing of AB 32, the Health and Safety Code (Section 38501, Subdivision (a)) now states the following:

> "Global warming poses a serious threat to the economic well-being, public health, natural resources, and the environment of California. The potential adverse impacts of global warming include the exacerbation of air quality problems, a reduction in the quality and supply of water to the state from the Sierra snowpack, a rise in sea levels resulting in the displacement of thousands of coastal businesses and residences, damage to marine ecosystems and the natural environment and an increase in the incidences of infectious diseases, asthma, and other human health-related problems."

The bill requires the CARB, in coordination with State agencies as well as members of the private and academic communities, to adopt regulations to require the reporting and verification of statewide GHG emissions and to monitor and enforce compliance with this program. Similar to Executive Order S-3-05, under the provisions of the bill, by 2020, statewide GHG emissions will be limited to the equivalent emission levels in 1990. By January 2008, the CARB will determine the statewide GHG emission level in 1990 through review of the best available scientific, technological, and economic information, as well as provide opportunities for public review and comment. To achieve the 2020 reduction goal, by January 2011, the CARB shall adopt emission limits and reduction measures, which may include a system of market-based declining annual aggregate emission limits for sources or categories of sources that emit GHGs. It is anticipated that limits and emission standards adopted by the CARB will become operative beginning January 2012. In addition, the Climate Action Team established by the Governor to coordinate the efforts set forth under Executive Order S-3-05 is expected to continue its role coordinating overall climate policy.

12.2.4 Senate Bill 1368

Senate Bill (SB) 1368 is the companion bill of AB 32 and was signed by Governor Schwarzenegger in September 2006. SB 1368 requires the California Public Utilities Commission (PUC) to establish a GHG emission performance standard for baseload generation from investor-owned utilities by February 1, 2007. The California Energy Commission (CEC) must establish a similar standard for local publicly owned utilities by June 30, 2007. These standards cannot exceed the GHG emission rate from a baseload combined-cycle natural gas fired plant. The legislation further requires that all electricity provided to California, including imported electricity, must be generated from plants that meet the standards set by the PUC and CEC.

12.3 POTENTIAL IMPACTS TO ENVIRONMENTAL RESOURCES IN CALIFORNIA RESULTING FROM GLOBAL CLIMATE CHANGE

Global climate change has the potential to impact numerous environmental resources in California through potential, though uncertain, impacts related to future air temperatures and precipitation patterns, and the resulting implications to surface water runoff rates and timing, water temperatures, reservoir operations, and sea levels. Although current models are broadly consistent in predicting probable increases in global air temperatures and levels of GHG's resulting from human activities, there are considerable uncertainties about precipitation

estimates. For example, many regional modeling analyses conducted for the western United States indicate that overall precipitation will increase, but uncertainties remain due to differences among larger-scale General Circulation Models (GCMs).[10] Some researchers believe that climate warming might push the storm track on the West Coast further north, which would result in drier conditions in California. At the same time, relatively newer GCMs, including those used in the National Water Assessment, predict increases in California precipitation.[11] Similarly, two popular climate models, including HadCM2 developed by the U.K. Hadley Center and PCM developed by the U.S. National Center for Atmospheric Research also predict very different future scenarios. The HadCM2 predicts wetter conditions while the PCM predicts drier conditions in the greater Central Valley.[12]

While much variation exists in projections related to future precipitation patterns, all available climate models predict a warming trend in California resulting from the influence of rising levels of GHGs in the atmosphere.[13] In 2004, the Intergovernmental Panel on Climate Change (IPCC) stated that it is very likely that hot extremes, heat waves, and heavy precipitation events will be more frequent.[14] The potential effects of a warmer climate on the seasonality of runoff from snowmelt in California's Central Valley have been well-studied and results suggest that melt runoff would likely shift from spring and summer to earlier periods in the water year.[15] Currently, snow accumulation in the Sierra Nevada acts as a natural reservoir for California by delaying runoff from winter months when precipitation is high.[16] Despite the uncertainties about future changes in precipitation rates, it is generally believed that higher temperatures will lead to changes in snowfall and snowmelt dynamics. Higher atmospheric temperatures will likely increase the ratio of rain to snow, shorten and delay the onset of the snowfall season, and accelerate the rate of spring snowmelt, which would lead to more rapid and earlier seasonal runoff relative to current conditions.[17] Studies suggest that the spring streamflow maximum could occur about one month earlier by 2050.[18] Further, droughts have been and are expected to increase in duration and frequency in the future.[19]

12.4 CLIMATE CHANGE CASE STUDIES IN THE CALIFORNIA CENTRAL VALLEY

Projecting the regional impacts of climatic change and variability relies first on GCMs, which develop large-scale scenarios of changing climate parameters, usually by comparing scenarios with different concentrations of GHGs in the atmosphere. However, information provided by the GCMs is typically too coarse of a scale to make accurate regional assessments.[20] Consequently, recent efforts have resulted in reducing the scale and increasing the resolution of climate models by downscaling or integrating regional models into the global models.

Both GCMs and hydrologic models (i.e., CALSIM) have been utilized in a number of California climate change studies. Many of these studies focus on stream flow response to shifts in the timing and form of precipitation, and do not address inter-annual variability or scaling issues inherent in mapping GCM model output to more detailed watershed hydrologic models.[21] As a result, such studies do little more than make qualitative statements about the implications of these changes to environmental impacts (e.g., water quality, agriculture, fisheries).[22] However, other investigations have attempted to quantify impacts to environmental resources, particularly water supply.

Such efforts have focused attention on the issues of water management in California associated with potential hydrologic changes that may occur as a result of climate change. More recently, there has been progress in modeling climate change and its effects on a regional basis. Although there are still differences in some model projections (e.g., amount and timing of annual precipitation), projections on other variables are becoming more consistent (e.g., reduced

snowpack, shift of snowmelt timing to an earlier time period, rises in sea level, and warmer weather patterns). Though differences in the hydrological response to climate change exist among model projections, these differences can be used to bracket the magnitude of expected changes allowing managers to develop different response scenarios. Some of the key findings of recent research efforts in the Central Valley of California are described below.

12.5 2005 UPDATE TO THE DEPARTMENT'S CALIFORNIA WATER PLAN

The 2005 update to the *California Water Plan*[23] contains an analysis of future water demands resulting from population growth, and additionally attempts to address potential impacts resulting from global climate change, as discussed below. The Department has developed preliminary estimates of water demands that could reasonably be expected to occur by 2030. These preliminary estimates represent the expected water demands under three different future scenarios. The three future scenarios are defined as follows:

Scenario 1 – Current Trends: Recent trends for population growth and development patterns, agricultural and industrial production, environmental water dedication, and naturally occurring conservation measures (e.g., plumbing code changes, natural replacement, actions water users take on their own, etc.).

Scenario 2 – Less Resource Intensive: Recent trends for population growth, higher agricultural and industrial production, more environmental water dedication, and higher naturally occurring conservation.

Scenario 3 – More Resource Intensive: Higher population growth rate, higher agricultural and industrial production, no additional environmental water dedication, and lower naturally occurring conservation.

The greater urban water demand projected under all three scenarios presents significant challenges to water managers. Under the Current Trends scenario, the Department estimates an additional 3.6 million acre-feet of urban and environmental water demand per year in 2030. Though there may be commensurate reductions in agricultural demand, this demand reduction would occur in the Central Valley, while much of the additional urban demand would occur in the southern part of the State, and the ability to transfer additional water there could be constrained by conveyance facilities, area-of-origin issues, environmental impacts, and other third party effects. Although these projections describe additional water demands in California by 2030, they do not consider the capability of the water management system to meet those demands under different hydrologic conditions such as those predicted by climate change models.

The 2005 *California Water Plan* also attempts to address concerns related to climate change. More specifically, the Department recognizes the potential for significant impacts associated with climate change, and these impacts warrant an examination regarding the ability of existing water supply infrastructure and natural systems to accommodate or adapt to climatic change. The 2005 *California Water Plan* identified the following needs:

- The major tool for evaluating the impact on major water project systems is CALSIM, a model developed jointly by Reclamation and the Department. CALSIM currently relies on historic monthly hydrological data to assess project impacts. The development of modified input to CALSIM from the climate models is a major task and will require help from the research community. Enabling CALSIM to utilize data from climate models will allow for more proactive planning and development of strategies and options for improving water supply and quality;

- The linking of climate and hydrologic models is a major task but will provide a tool for evaluating multipurpose reservoir flood control aspects. The screening of climate models by experts in the field will be required to select those that provide the most plausible future scenarios. Because there will be competition between flood control and other purposes at the large multipurpose reservoirs due to earlier peak snowmelt runoff, an examination of space criteria allocated for flood control in the spring is required;
- Because of a general warming in California's climate, it is expected that increases in water requirements for crops, wildlands and landscaping will likely occur. In order to properly measure these changes, the monitoring of evapotranspiration rates will be required. The goal is to develop likely changes in evapotranspiration rates for the 2050 and 2100 scenarios. Projections of future weather including precipitation during the growing season are required to provide projected increases in plant water requirements;
- Existing models for water temperature on the major rivers in the Sacramento River Basin will likely require improvement as the job of maintaining suitable downstream temperatures for anadromous salmonids becomes more difficult; and
- Monitoring the effects of climate change on regions near California is also important. The Colorado River region is important to California and may have potential impacts on both water supply and hydropower. The Columbia River Basin is an important source of hydropower for California. Monitoring the results of research and studies in these areas is important for future planning studies.

Because only limited data and tools exist to provide answers to important questions for decision makers, water managers and resource planners, the Department is working in conjunction with others to develop a new analytical approach for the preparation of *California Water Plan Update* 2009. The Department has determined that designing this quantitative approach will best be achieved through a consortium of public and private entities, with State leadership and input from stakeholders. The purpose of the consortium is to prepare a long-term plan to review data and analytical tools, as well as to develop decision-support systems to make complex technical information more accessible to decision makers and resource managers. Because time is needed to develop this new approach, most of the quantitative work will be published in 2010.

12.6 PRELIMINARY CLIMATE CHANGE IMPACTS ASSESSMENT FOR CVP/SWP OPERATIONS AND THE DELTA

On July 9, 2006, the Department released a report entitled *Progress on Incorporating Climate Change into Management of California's Water Resources* (Report).[24] The Report was prepared in response to Executive Order S-3-05 by the Governor in June 2005 and as a first step in addressing the limitations presented above. The Report describes the Department's progress toward incorporating climate change modeling into existing water resources planning and management tools and methodologies. While the Report describes numerous efforts, Chapters 4 and 5 of the report present the potential impacts of climate change scenarios on CVP/SWP operations and deliveries, and Delta water quality and water levels using the hydrologic models CALSIM II and DSM2, respectively. Each impact analysis considers four scenarios predicted by pairings of two global climate models (i.e., PCM and GFDL) and two carbon dioxide emissions rates (A2 and B1), and illustrate projected hydrologic conditions centered around 2050 (i.e., 2035 through 2064). All four climate change scenarios predict a general warming trend for California; however, three of the four scenarios predict modestly drier climates, while one (i.e., PCM-B1) predicts a weak precipitation increase. Monthly river inflow data for use as CALSIM II input is generated by downscaling and adapting global climate model results, using a regional hydrologic model, derivation of climate change runoff perturbation

ratios, and application of these perturbations ratios to CALSIM II historic reservoir inflows. The hydrologic estimates associated with each climate change scenario are then compared to a base scenario, which is designated as the 2020 level of development outlined in U.S. Bureau of Reclamation's *Long-Term Operations Criteria and Plan* (OCAP).[25]

The results of the analysis for CVP/SWP operations and deliveries indicate several potential impacts related to global climate change. For example, during the three drier year climate scenarios, there are a significant number of months in which Shasta and Folsom reservoirs fall to dead storage, with these occurrences concentrated during critical and drought-year conditions. During these months, stream flow requirements in the Sacramento and American rivers could not be met, and the CVP was unable to meet its share of water for the Coordinated Operations Agreement. In contrast, the base scenario had only one month which resulted in attainment of dead storage in these locations. These reservoir shortages influence the remaining analyses within the model, and hence, CVP/SWP system deliveries also are influenced by global climate change. Relative to the base scenario, changes in annual average south-of-Delta SWP Table A and CVP deliveries ranged from slight increases associated with the wetter-climate scenario up to about 10 percent reductions for drier year scenarios. In addition, carryover storage for both the CVP and SWP reservoir is negatively impacted under the drier climate scenarios and mildly increased under the wetter-climate scenario. Additional reservoir operations impacts are evident by a reduction in the CVP/SWP power generation capacity during summer months and warming of water temperatures in rivers downstream of CVP/SWP reservoirs under the drier-climate scenarios.

Using the same methodology and reservoir operation output described above, the Report also describes potential impacts of climate change on Delta water quality and water levels. The CALSIM II output reflecting adjustments in reservoir operation and Delta exports due to shifting precipitation and runoff patterns are utilized in the DSM2 model for each of the four scenarios. Because one of the key assumptions in the CALSIM II model prioritizes Delta water quality standards, the impact assessment for the Delta inherently mitigates for climate change by modifying upstream system operations to maintain Delta water quality standards. Hence, Delta water quality effects for all four climate change scenarios are relatively minor. When considering a one-foot rise in sea level, either alone or combined with the effects of climate change, Delta water quality standards are met about 90 percent of the time, particularly during dry and critical years. In real time, operational adjustments would be required and translate into impacts to the CVP and SWP, although these impacts cannot yet be quantified. Finally, the Report predicts that levee overtopping could be an issue during a one-foot sea level rise scenario, although no overtopping events are predicted for the current sea level condition.

As noted in the Report, the purpose of the study is to demonstrate how various analysis tools currently used by management agencies could be used to address issues related to climate change. The Report explicitly cautions that all results presented are preliminary, incorporate several assumptions, reflect a limited number of climate change scenarios, and do not address the likelihood of occurrence for potential impacts, and as such, are not sufficient by themselves to make policy decisions. In addition, the study contains several key assumptions that may not reflect operational realities. For instance, the study assumes that no changes will be made to system structures or facilities, reservoir operating rules, stream flow requirements, water quality standards, or operations to account for sea level rise or salt water encroachment. Future work will focus on further elucidating not only the magnitude, but also probability, of potential impacts, as well as investigating possible changes in system operations to avoid these impacts.

Some of the projected effects of climate change on California's water resources and the consequences of those effects are summarized in Table 12-1.

TABLE 12-1

POTENTIAL EFFECTS OF CLIMATE CHANGE ON CALIFORNIA'S WATER RESOURCES AND EXPECTED CONSEQUENCES

Potential Water Resource Impact	Expected Consequence
Reduction of the State's average annual snowpack	• Potential loss of 5 million acre-feet or more of average annual water storage in the State's snowpack • Increased challenges for reservoir management and balancing the competing concerns of flood protection and water supply
Changes in the timing, intensity, location, amount, and variability of precipitation	• Potential increased storm intensity and increased potential for flooding • Possible increased potential for droughts
Long-term changes in watershed vegetation and increased incidence of wildfires	• Changes in the intensity and timing of runoff • Possible increased incidence of flooding and increased sedimentation
Sea level rise	• Inundation of coastal marshes and estuaries • Increased salinity intrusion into the Sacramento-San Joaquin River Delta • Increased potential for Delta levee failure • Increased potential for salinity intrusion into coastal aquifers (groundwater) • Increased potential for flooding near the mouths of rivers due to backwater effects
Increased water temperatures	• Possible critical effects on listed and endangered aquatic species • Increased environmental water demand for temperature control • Possible increased problems with foreign invasive species in aquatic ecosystems • Potential adverse changes in water quality, including the reduction of dissolved oxygen levels
Changes in urban and agricultural water demand	• Changes in demand patterns • Changes in evapotranspiration rates

Some of the main results of the Report related to impacts on the SWP and CVP are as follows:

- In three of the four climate scenarios simulated, there were significant shortages predicted in CVP north-of-Delta reservoirs during droughts. In future studies, operational changes are necessary to avoid these shortages. At this time, it is not clear whether the necessary changes in operations will be insignificant or substantial.
- Estimated changes in annual average SWP south-of-Delta Table A deliveries ranged from a slight increase of about one percent for a wetter scenario to about a 10 percent reduction for one of the drier climate change scenarios.
- Estimated increased winter runoff and lower Table A allocations resulted in slightly higher annual average Article 21 deliveries in the three drier climate change scenarios. However, the boosts 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.
- Estimated 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. The CVP results of the drier climate change scenarios are in question due to the north-of-Delta shortages mentioned above. These shortages will have to be addressed in future climate change studies.

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

Sea level rise effects on water project operations to repulse greater salt water intrusion under these conditions were not examined due to lack of existing tools for that type of analysis. Surrogates to provide an indication of the increased operation challenges from sea level rise are discussed in the report; future work in this area will include the development of the necessary tools to quantify the impacts of sea level rise on saltwater intrusion and the incremental water supply impacts to repulse greater saltwater intrusion forces into the Delta.

Some of the main results of the climate change report related to estimated impacts on the Delta include:

- For the four climate change scenarios, Delta inflows typically increase during the late winter and early spring and decrease during the summer and fall. On average, Delta exports are reduced with the largest reductions occurring during the summer and fall. Inflows and exports are most sensitive to climate change during extremely wet or extremely dry periods.
- Flexibility in the system to modify reservoir operations and Delta exports for the climate change scenarios at present sea level 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 estimated chloride concentrations below the 250 milligram per liter (mg/l) threshold 90 percent of the time at Old River in Rock Slough. In real time, operational adjustments will take place so these effects will translate into water supply impacts to the SWP and CVP. As stated above these impacts to water supply cannot be quantified at this time. Maintaining chloride concentrations below the 150 mg/l threshold was also more challenging during critical and dry years. These results indicate the need to develop a tool to quantify the additional water supplies that would need to be dedicated to repulse sea water in order to maintain Delta water quality under sea level rise conditions.
- There was complete compliance with the chloride standards at the SWP and CVP for the climate change at present sea level scenarios. Chloride concentrations remained below threshold values for the sea level rise and combined climate change and sea level rise scenarios.
- Chloride mass loadings at the municipal and industrial intakes are typically reduced for the climate change only scenarios due to lower export rates. Increased intrusion of salt water from the ocean from the sea level rise and combined climate change and sea level rise scenarios lead to increased chloride mass loadings at the municipal and industrial intakes.
- For a one foot rise in sea level, maximum daily water levels exceeded the minimum levee crest elevation on Sherman Island twice during the 16-year analysis period. Water levels did not exceed the minimum crest elevation for present sea level conditions.

12.7 AREAS OF FURTHER RESEARCH AND ONGOING ACTIVITIES

One of the most important areas of research associated with the potential impacts of climate change on California's water resources is the further development of tools to predict changes in the timing or amount of future water availability. Currently, CALSIM serves as the primary

operations and planning model for CVP and SWP operations. The model simulates CVP and SWP operations within the geographical area affected by CVP and SWP facilities, including the Delta, on a monthly time-step over a range of historical hydrologic conditions. CALSIM routes water through the system on a monthly basis using operational decisions, which consider delivery and storage targets, and adhere to operating rules and constraints such as instream flow requirements, downstream water quality objectives and contract deliveries to agricultural and M&I water users. The end-of-month storages from each month's operations are used as initial conditions for the following month's operations. Model outputs include monthly reservoir releases, river flows, reservoir stored water volumes, Delta export activities, indicators of Delta water quality, and water deliveries.[26] A baseline version of the model is set up to perform monthly operations decisions for a 73-year simulation period based on the 1922 to 1994 period of hydrologic record. For comparative studies, water demands, system infrastructure, and/or operations are modified to represent CVP and SWP operations under alternate conditions.

Another simulation model that has been used for studies in the Central Valley is Central Valley Model (CVMod). CVMod was developed by the University of Washington and operates similarly to CALSIM. The primary input to CVMod is monthly streamflow which comes from either observed historic streamflows or from Variable Infiltration Capacity (VIC) simulations of potential future streamflows; VIC is a regional hydrologic model implemented for the Sacramento-San-Joaquin basins.[27] In a comparison of CALSIM with CVMod, it was shown that CALSIM was better able to predict end-of-month storage volumes in the major Central Valley Reservoirs. The period of analysis for the comparison was October of 1979 through June of 1994.[28]

A third model used in some Central Valley studies is California Value Integrated Network (CALVIN). CALVIN was developed at University of California Davis and is a prescriptive optimization model that operates surface and groundwater resources and allocates water over the historical hydrologic record.[29] CALVIN maximizes the economic values of agricultural and urban water use statewide, within physical, environmental and policy constraints. Besides the Central Valley, CALVIN incorporates parameters from southern California SWP contractors, California users of the Colorado River, the Owens Valley and Mono Basin and also groundwater sources, making it the model with the broadest coverage of water users in California. Monthly operations and allocation decisions are made based on the 1922 to 1993 hydrologic period assuming perfect foresight of future inflows.

To effectively assess the potential impacts of climate change on California's water system, a model is needed that represents the operation of the system and has the ability to accept input from climate change impact studies related to the Central Valley. The model requires a descriptive, rather than prescriptive approach.[30] A descriptive approach would use observed data in the model without regulatory limits on operations to represent a more realistic view of the operation of California's water system. A purely prescriptive approach would include presumed operational limitations to show how the system works with adherence to those limitations. Of the three models described above, CALSIM provides the most robust representation of the current system in terms of coverage, spatial representation and operational rules. CALSIM's major fault is its inability to utilize hydrologic data not related to the 73 years of historical data for which the model has been validated. CVMod has the ability to accept any hydrologic inputs, however, its weakness is that some of the operations rules, and hence, the results from the model, are potentially much different from how the system is actually run. The CALVIN model is prescriptive rather than descriptive.

Projecting regional impacts of climate change is a multi-step process. First, GCMs are used to develop large-scale scenarios of changing climate parameters. Because this information is at

too coarse a scale to make regional assessments, efforts are currently being made to reduce the scale and increase the resolution of GCMs by downscaling or integrating regional models into the GCMs. VanRheenen *et al.* (2004) were able to incorporate output data from PCM models into CVMod to examine the Central Valley water resources, under five different PCM scenarios, by developing a technique to downscale PCM model output to a scale suitable for CVMod input. Dettinger *et al.* (2004) was able to utilize a downscaled PCM model output to simulate streamflow and water balances in the American River basin by use of the Precipitation-Runoff Modeling System (PRMS), a model that predicts changes to runoff based on land use and climate changes. Zhu[31] utilized CALVIN to process 12 climate change scenarios developed by the Lawrence Berkeley National Laboratory (LBNL). In this study, LBNL data was used to alter the CALVIN base hydrology, consisting of monthly time series of rim inflows, reservoir evaporation rates, local accretions and groundwater inflows, to simulate projected hydrology under different climate change scenarios.

Although significant differences among GCMs currently exist in projected future climate scenarios, the research described above indicates that substantial progress has been made in developing methodologies to integrate hydrologic models with climate models. Ideally, the ability to integrate GCM output with CALSIM will provide a tool to allow the proactive planning and development of options to improve water supply and quality under different climate change scenarios. Integration of the GCMs with CALSIM will likely require several intermediate steps that will include downscaling of the GCMs and may include features from CALVIN, CVMod and PRMS. The Report has made significant strides in integrating GCMs into CALSIM, although several limitations remain.

Both government agencies and the private sector have recognized the potentially adverse impacts associated with climate change. Businesses in the private sector are voluntarily cutting their GHG emissions while state and local governments are responding with efforts to cut emissions within their jurisdictions.[32] Additionally, the federal government has set a goal of reducing GHG intensity by 18 percent over the next decade. GHG intensity is a measure of green house gas emissions per defined unit. For example, GHG intensity could be reported as tons of GHG emissions per capita or per million dollars of gross domestic product.

Within California, the Climate Action Team established by Executive Order S-3-05, coordinates all State-level actions relating to climate change. Under the umbrella of the Climate Action Team, the different state resource agencies are actively engaged in various activities specifically related to climate change. For example, the Department is helping the State prepare for climate change through its water resource planning and forecasting activities; CDFG is addressing the issue of adaptation to climate change with regional conservation planning, watershed planning, fisheries management and restoration, and biological assessment; and the California Energy Commission's Public Interest Energy Research (PIER) program is addressing climate change by leading the development of a long term climate change research program for California and is seeking to improve understanding of the implications of climate change by supporting research on potential impacts and possible adaptation and mitigation measures. Additionally, several campuses of the University of California are actively engaged in climate change research.

Through development of a functional water management tool capable of incorporating climate change data, reductions in GHG emissions, and proper resource planning, California will continue preparing for climate change impacts.

12.8 CLIMATE CHANGE AND SWP DELIVERIES WITH PROPOSED PROJECT

The implications of climate change for the proposed project and this EIR are dependent on changes in temperatures and rainfall in California. As noted earlier, in some scenarios, there could be future decreases in Table A allocations in the drier scenarios and fewer opportunities for Article 21 deliveries. The degree to which these effects will be felt between now and 2020 has not been studied and remains unknown. Therefore, climate change was not incorporated into the CALSIM II modeling for this EIR for this reason and because of the limitations stated previously. As new tools are developed and additional trends identified, analytical tools will become available to conduct such analyses.

The analyses prepared to date suggest that there could be a decline of up to 10 percent in the long-term (2035 to 2064) average Table A supplies to SWP contractors, assuming no changes in existing SWP facilities and operations, as a result of climate change. While that decline is not projected to become evident until well beyond the time frame of this EIR, it is nonetheless an important finding with respect to dependence on SWP supplies in the long term.

The process used by the Department to allocate water among its contractors is already structured to deal with Table A supplies that are less than full Table A amounts. The Department routinely allocates annual supplies less than 100 percent of Table A. If the amount of water available to allocate each year declined by an average of 10 percent, the various allocation methods evaluated in this EIR could all still be applied in their present form. The relative allocations among contractors would remain the same with lower Table A allocations, although each contractor would get less, and under the allocation methods for the no project alternatives, agricultural contractors would get much smaller allocations more often. Therefore, allocation methods which eliminated the agriculture-first shortage provision, as does the proposed project, have helped agricultural contractors better deal with the potential effects of climate change.

SWP supplies are likely to become less reliable over the long term, assuming current SWP facilities remain unchanged. The shortened runoff period is likely to result in greater difficulty in filling San Luis Reservoir. This phenomenon will reduce the frequency of times when added water can be pumped from the Delta to provide water for storage outside of contractor's service areas, and thus impacts of the proposed project on the Delta may be less than predicted elsewhere in this EIR.

According to the Department's Report, there could be additional times when Article 21 water would be available, but that added (and intermittent) supply would not be sufficient to offset declines in Table A allocations. Because there may be fewer years when San Luis Reservoir fills, there may be fewer years when Article 21 water can be offered. There would be increased winter runoff at times when the snow level is higher and the runoff more copious than past periods, but if San Luis Reservoir cannot be refilled from its low point within the available window when permitted pumping exceeds contractor demand (the total pumping rate is constrained by environmental and water quality regulations as well as fish protection measures), the total amount of Article 21 water that can be delivered could also decline, contrary to indications in the Department's Report.

It is possible to provide a representation of the impacts of climate change on the baseline and proposed project scenarios described in Chapter 6 by using allocation data developed under scenario GFDL B1 as computed in the Department climate change Report. This climate change scenario has been developed by first computing the annual differences in SWP allocations

computed using CALSIM under climate change Scenario GFDL B1 compared to those in the baseline runs for the climate change report. Those differences were then applied to the allocations computed in the model runs for the baseline scenario and the proposed project. The results are shown in Table 12-2. Table A deliveries would decrease by 10 to 25 percent under the baseline scenario and with the proposed project with the greatest effects occurring in critically dry years. The differences between the baseline scenario and the proposed project are negligible, indicating that the Table A transfers and altered water allocation procedures have no effect on the SWP's vulnerability to climate change.

TABLE 12-2

POTENTIAL EFFECTS OF CLIMATE CHANGE ON TABLE A DELIVERIES IN THE FUTURE (2020) BY WATER YEAR TYPE[a]

Year Type	Baseline	Baseline with Climate Change	% Reduction	Proposed Project	Proposed Project with Climate Change	% Reduction
Average	3203.8	2866.2	10.5	3189.3	2853.0	10.5
Wet	4004.6	3826.2	4.5	3964.1	3787.3	4.5
Above Normal	3893.4	3528.4	9.4	3865.1	3502.2	9.4
Below Normal	3553.9	3093.1	13.0	3560.0	3097.7	13.0
Dry Years	2763.4	2326.2	15.8	2756.2	2323.8	15.7
Critical Years	1330.2	998.0	25.0	1341.0	1007.6	24.9

Note:
a. The reduction levels are based on the Department's Report which represents potential changes centered around 2050 (see page 12-12).

The main conclusion of this analysis is that there would be less reliability for all SWP contractors overall, assuming no changes in current SWP facilities. The largest reductions would tend to occur in the drier years. In addition, under the agriculture-first shortage alternatives, there would be greater dry year impacts on agricultural contractors and more water available to urban contractors in those dry years than with the proposed project.

Sea level rise would also affect the ability of the Department to allocate Table A supplies while meeting Delta water quality standards, especially salinity standards. As sea levels gradually rise (both from warming of the oceans and melting ice caps), and the land within Delta islands continues to oxidize and the islands drop lower below current sea level, the risk of catastrophic failure of islands increases.

Without robust and extensive emergency response planning and action, such catastrophic failure of multiple Delta levees would draw in seawater to the Delta that might take up to a year or more to repulse with fresh water. During such periods, the SWP would be unlikely to be able to provide any water supplies to the 24 contractors located downstream of the Banks pumps, leaving those agencies to rely exclusively on local and other imported water supplies. The CVP contractors served from the Jones (formerly Tracy) pumps would similarly be unable to obtain normal Delta supplies, and would draw heavily on groundwater.

Climate change would increase pressure on other local and imported supplies to meet demand, and would also tend to intensify conservation measures as water supplies became less reliable. Catastrophic loss of Delta water supplies would have widespread impact on water availability, would increase groundwater extraction and exacerbate groundwater overdraft, would have

economic impacts on agriculture, industry, and quality of life, and would further impact local and imported supplies.

Overall, given current SWP facilities, SWP water supplies will become less reliable under the trends that have been identified with climate change with or without the Monterey Amendment. As noted by the Department's director, current and future droughts are likely to be deeper and longer than historical droughts and conservation efforts need to be redoubled.[33]

12.9 PROPOSED PROJECT GREENHOUSE GAS EMISSIONS

The proposed project could result in some added GHG emissions as a result of post-Monterey Amendment SWP operations. The generation of power to supply the added pumping at SWP facilities would require additional consumption of energy from power plants in the western U.S. that emit GHGs (see Section 7.16, Energy). The Department is reducing its reliance on fossil-fuel power and exploring alternative power options. For example, by a recent letter addressed to the Nevada Power Company, the Department has stated that it will not renew its existing contract for power from the coal-fired Reid Gardner power plant when that contract expires in July 2013.[34] The power from this plant is primarily used for operations to pump water to SWP contractors. The Department is currently seeking replacement of this power supply with alternative power sources. In addition, in an effort to reduce the Department's carbon footprint, it has recently filed an intent to register with the California Climate Action Registry to complete a full assessment of energy use and GHG emissions from the SWP and to plan its future energy portfolio.[35] Further, future power use trends could be partly offset if SWP deliveries decline, requiring less purchased power to operate the SWP, although clean hydropower generation at Oroville and other SWP facilities would also decline somewhat under a lower delivery scenario.

Also, to the extent that the proposed project has allowed or will allow additional urban growth, that growth could also result in additional on-going emissions of GHGs. Because any such emissions become part of the atmosphere and are disbursed globally, the relevant issue is whether the growth in the areas affected by the proposed project would result in greater or lesser impacts than alternate locations for housing and employment development. At present, there is no mechanism to develop such a comparison. However, much of California's urban development is highly dependent on land use planning decisions made at the local level and the use of automobiles for transportation. As such, there may be a net increase in emissions of GHGs from development in California. As discussed in Chapter 8, the proposed project may result in changes in growth patterns at the local level, but would have no effect on statewide population growth. Thus, within the SWP service area as a whole, the proposed project would not result in any changes in GHG emission due to growth.

Neither the CARB nor any air district in California has identified significance thresholds for GHG emissions or a methodology for analyzing air quality impacts related to GHG emissions. The state has identified 1990 emission levels as a goal through adoption of AB 32. To meet this goal, California would need to generate lower levels of GHG emissions than current levels. However, no standards have yet been adopted quantifying 1990 emission targets. It is recognized that for most projects there is no simple metric available to determine if a single project would help or hinder meeting the AB 32 emission goals. In addition, at this time AB 32 only applies to stationary source emissions. Yet, consumption of fossil fuels in the transportation sector accounted for over 40% of the total GHG emissions in California in 2004. Current standards for reducing vehicle emissions considered under AB 1493 call for "the maximum feasible reduction of GHGs emitted by passenger vehicles and light-duty trucks and

other vehicles," and do not provide a quantified target for GHG emissions reductions for vehicles.

Emitting CO_2 into the atmosphere is not itself an adverse environmental affect. It is the increased concentration of CO_2 in the atmosphere resulting in global climate change and the associated consequences of climate change that results in adverse environmental affects (e.g., sea level rise, loss of snowpack, severe weather events). Although it is possible to generally estimate a project's incremental contribution of CO_2 into the atmosphere, it is typically not possible to determine whether or how an individual project's relatively small incremental contribution might translate into physical effects on the environment. Given the complex interactions between various global and regional-scale physical, chemical, atmospheric, terrestrial, and aquatic systems that result in the physical expressions of global climate change, it is impossible to discern whether the presence or absence of CO_2 emitted by the proposed project would result in any altered conditions.

While it is not possible to determine whether the proposed project individually will have a significant impact on global warming or climate change, it is evident that the project will contribute to cumulative GHG emissions in California. The SWP's total GHG emissions are currently estimated at 0.6 percent of statewide emissions. As described in Section 7.16, the proposed project will increase SWP power use by approximately 2.02 percent over existing power use, thus an increase of 2.02 percent in the SWP's GHG emissions is possible. This would still be only a tiny fraction of the statewide GHG emissions, and would not make it substantially more difficult for the State to achieve the GHG reductions required by AB 32. However, without the necessary science and analytical tools for project-level effect, it is not possible to determine with certainty, whether the project's GHG emissions will be cumulatively considerable, within the meaning of CEQA Guidelines Sections 15065(a)(3) and 15130.

CARB is currently in the process of designing regulations to monitor, limit, and ultimately reduce California GHG emissions but there are as yet no clear standards for assessing the significance of cumulative impacts from projects. Under CEQA, the more severe the environmental problem, the lower the threshold for treating a project's contribution to cumulative impacts as significant. It is possible, in the future when GHG emissions guidance is forthcoming, that the contributions to climate change from projects of similar scale to this one will be considered cumulatively considerable. Given the findings of AB 32, incorporated into California law, stating that global warming poses serious threats to health and the environment the requirements of CEQA for the lead agency to determine that a project not have a cumulatively considerable contribution, the lack of guidance for determining the significance of cumulative impacts to climate change from projects, and out of an overabundance of caution, the proposed project's emissions could be considered cumulatively considerable. This determination is based upon a lack of clear scientific and regulatory criteria for determining the level of significance of the project's contribution.

The Department is already committed to reducing GHG emissions from operations of the SWP, which would offset the minor increases in GHG emissions from the proposed project and help the State achieve the goals of AB 32. These commitments include registering with the California Climate Action Registry, replacing power purchased from the coal-fired Reid Gardner Power Plant with cleaner energy sources, and other measures to reduce the SWP's carbon footprint. The significant reductions anticipated in GHG emissions from the SWP will more than mitigate the relatively minor increase in GHG emissions and cumulatively considerable impact attributable to the proposed project.

12.10 CONCLUSIONS

According to a recently published California Energy Commission report titled, *Climate Change and California Water Resources: A Survey and Summary of the Literature*:[36]

> "Managing water resources to address climate change impacts could prove to be different than managing for historical climate variability for several reasons, including: (1) climate changes could produce hydrologic conditions and extremes of a different nature than current systems were designed to manage; (2) they may produce similar kinds of variability, but that are outside of the range for which current infrastructure was designed; (3) traditional water resource management assumes that sufficient time and information will be available before the onset of large or irreversible climate impacts to permit managers to respond appropriately; and (4) traditional management assumes that no special efforts or plans are required to protect against surprises or uncertainties."

Although considerable uncertainties regarding the exact impacts of climate change on California hydrology and water resources will remain until there is more accurate and consistent information about how precipitation patterns, timing, and intensity will change, considerable progress is being made to develop methodologies and tools to incorporate future climate change scenarios into current hydrologic models. Additionally, one of the most important results for water managers also has been the one most consistently predicted to occur. It is quite likely that there will be increases in winter runoff, decreases in spring and summer flows and higher peak flows. Therefore, managing water resources with a changing climate will likely prove different than managing for historic variability. Climate changes could produce hydrologic conditions and extremes of a different nature than current systems were designed to manage.

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