RECLAMATION

*Managing Water in the West*

## Technical Memorandum No. 86-68210-2016-08

# San Diego Watershed Basin Study

## Task 2.2 – Climate Change Impacts and Hydrologic Modeling

*Photo: El Capitan Reservoir*
*Source: https://www.wunderground.com/wximage/photoandy/2028*

**U.S. Department of the Interior**
**Bureau of Reclamation**
**Technical Service Center**

**May 2016**

# Mission Statements

The mission of the City of San Diego Public Utilities Department is to ensure the quality, reliability, and sustainability of water, wastewater and recycled water services for the benefit of the ratepayers and citizens served.

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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# San Diego Watershed Basin Study

## Task 2.2 – Climate Change Impacts and Hydrologic Modeling

*Prepared by:*

**Bureau of Reclamation**
**Technical Services Center**
**Water, Environmental, and Ecosystems Division (86-68200)**
**Water Resources Planning and Operations Group (86-68210)**
Daniel Broman, Hydrologic Engineer

*Peer reviewed by:*

Marketa McGuire, P.E., Hydrologic Engineer

**U.S. Department of the Interior**
**Bureau of Reclamation**
**Technical Service Center**

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# Acronyms and Abbreviations

| | |
|---|---|
| AR | Assessment Report |
| BCSD | Bias-Correction Spatial Disaggregation |
| CA DWR | California Department of Water Resources |
| CRB | Colorado River Basin |
| CMIP3 | Coupled Model Intercomparison Project Phase 3 |
| CMIP5 | Coupled Model Intercomparison Project Phase 5 |
| CT | Current Trends |
| DCHP | Downscaled Climate and Hydrologic Projections |
| DWR | California Department of Water Resources |
| EG | Expanded Growth |
| GCM | General Circulation Model |
| ES | Executive Summary |
| GHG | greenhouse gas |
| HDe | Ensemble-informed hybrid delta method |
| IID | Imperial Irrigation District |
| IPCC | Intergovernmental Panel on Climate Change |
| MAF | million acre-feet |
| MWD | Metropolitan Water District of Southern California |
| QSA | Quantification Settlement Agreement |
| RCP | Representative Concentration Pathways |
| Reclamation | United States Department of the Interior, Bureau of Reclamation |
| SDC Water Authority | San Diego County Water Authority |
| SECURE | Science and Engineering to Comprehensively Understand and Responsibly Enhance |
| SG | Slow Growth |

| | |
|---|---|
| SRES | Special Report on Emissions Scenarios |
| SSJ | Sacramento and San Joaquin |
| SWP | State Water Project |
| VIC | Variable Infiltration Capacity Model |
| WaterSMART | Department of the Interior's Sustain and Manage America's Resources for Tomorrow Water program |
| WSI | Water Supply Index |

# Executive Summary

The San Diego Watershed Basin Study (Basin Study) is being conducted jointly by the Bureau of Reclamation (Reclamation) and the San Diego County Water Authority (SDC Water Authority) to identify and evaluate current and future imbalances in water supply and demand, and explore alternatives for addressing future water management challenges. This Basin Study was conducted as part of Reclamation's Basin Studies Program as a means of fulfilling obligations outlined in the SECURE Water Act and the Department of the Interior's Sustain and Manage America's Resources for Tomorrow (WaterSMART) Program. The SDC Water Authority's current water supply is 80% imported, with the remaining 20% comprised of local water sources including surface water, groundwater, recycled water, and desalination. Imported water supplies come from the Colorado River and the State Water Project (SWP).

## Local Water Supplies – Methods and Summary

A long-term objective of the SDC Water Authority is to develop local water supplies and decrease the percentage of imported water used in the region. This report evaluates climate change impacts on these two water supply sources, describes data development to support this analysis, and describes additional analyses performed in other parts of the Basin Study. The Basin Study focuses on two future periods to complement the Water Authority's long-term planning efforts: the 2020s (represented by the ten water years 2020-2029) and the 2050s (represented by the ten water years 2050-2059). The reference historical period used for comparison against projected future conditions is the 1990s (represented by the ten years 1990-1999).

With respect to the analysis of climate change impacts on local water supplies, this Basin Study evaluated changes in natural streamflow using the Variable Infiltration Capacity (VIC) hydrologic model as a way of exploring impacts to both surface and groundwater sources. Projected changes in surface water were evaluated at three types of locations, namely, reservoir inflow locations, reservoir outflow locations, and river outlets. Changes in VIC simulated natural streamflow were evaluated on an annual basis, as well as for the cool season (December through March) and warm season (April through July). A majority of groundwater recharge in the region comes from streamflow infiltration. Thus, projected changes in groundwater were evaluated at locations where streams enter the groundwater basin. These locations were used as representative proxies for groundwater availability. Climate change impacts were evaluated at locations that correspond with recharge locations in the groundwater basins.

Climate change scenarios developed for evaluation of impacts on local water supplies are based on Coupled Model Intercomparison Project Phase 5 (CMIP5) climate model projections used in the Fifth Intergovernmental Panel on Climate Change (IPCC) Assessment. These projections have been downscaled in space and time to capture regional effects on climate, with two future emissions scenarios considered: Representative Concentration Pathways (RCP)4.5 and RCP8.5. By comparing computed measures for the 2020s and 2050s against a 1990s reference historical period, climate change impacts on local water supplies were evaluated. Using available downscaled General Circulation Model (GCM) projections for RCP4.5 and RCP 8.5, VIC simulated output was extracted from the downscaled archive of CMIP5 climate and hydrology projections developed by Federal and non-Federal agencies for a transient period from 1950-2099.

Projected changes in simulated natural streamflow are summarized in table Executive Summary (ES)-1 for all locations listed in Appendix A. The table illustrates that some increase in annual streamflow are projected under many of the scenarios and time periods. These increases are almost entirely driven by increases in cool season streamflow likely due to a combination of some precipitation increase and prevailing relatively cooler temperatures. These projected changes are consistent across all river basins in San Diego County. As with the surface water locations, moderate increases in annual streamflows at groundwater recharge sites were also driven by increases in cool season streamflow, somewhat outweighing moderate decreases in warm season streamflow.

Table ES-1.—Summary of Projected Changes in Seasonal and Annual Natural Streamflow for the 2020s and 2050s

| Future Time Period and Scenario | Change in Annual Natural Streamflow | Change in Cool Season (December – March) Natural Streamflow | Change in Warm Season (April – July) Natural Streamflow |
|---|---|---|---|
| 2020s RCP4.5 | +5% to +10% | +5% to +15% | -5% to +5% |
| 2020s RCP8.5 | +20% to +25% | +25% to +30% | +5% to +15% |
| 2050s RCP4.5 | +10% to +15% | +15 to +20% | 0% to -15% |
| 2050s RCP8.5 | -5% to +5% | +10 to +15% | 0% to -20% |

*Notes:* Ranges are representative of project change across all considered streamflow locations.

## Imported Water Supplies – Methods and Summary

With respect to analysis of climate change impacts on imported water supplies, this Basin Study evaluated changes based on results from two existing studies, namely the Colorado River Basin (CRB) Water Supply and Demand Study and the Sacramento and San Joaquin (SSJ) Basin Study. Imported water supply comes from two main sources: the Colorado River, and the State Water Project deliveries from the Sacramento and San Joaquin River systems. These two existing studies explored climate change impacts on these imported water supply sources to the San Diego region.

Evaluation of climate change impacts in imported water supplies was performed through analysis of relevant data and measures of supply reliability from the CRB Water Supply and Demand Study and the SSJ Basin Study. For the CRB Water Supply and Demand Study, six demand scenarios were incorporated ranging from slow growth to a continuation of growth following long-term trends. In addition, two management alternatives were also incorporated, namely a continuation of the 2007 Interim Operating Guidelines after 2026, which establish coordinated operations in years when shortage conditions are declared for the Lower Basin States, and a return to the no-action alternative.

Because the CRB Water Supply and Demand Study focused on future time periods that are different from this Basin Study, output data for all demand and management scenarios were obtained and four measures were re-computed for the analysis time periods in this Basin Study (2020s and 2050s). The four measures include:

- Lower Basin shortage volume of 1.5 million acre-feet (MAF) in 5 years
- Lower Basin shortage volume of 1.0 MAF in 2 years
- Lake Mead elevation threshold (1000 ft elevation, or 4.5 MAF storage volume)
- Mean annual shortages to Lower Basin States

Results from the analysis are summarized in table ES-2. Measures were summarized as the percentage of simulations exceeding the identified shortage volume. Across demand scenarios and management alternatives, the number of simulations with shortages in excess of these thresholds is fairly consistent for the 2020s future period. In addition, management under the Interim Operating Guidelines results in fewer shortages according to model simulations. Mean shortages to Lower Basin States followed this same pattern, in that there are fewer shortages under the Interim Operating Guidelines than the no action scenario.

SWP deliveries from the Banks Pumping Plant were evaluated in the SSJ Basin Study. This measure was re-computed for this Basin Study for the 2020s and 2050s. This study used five climate change scenarios based on an ensemble hybrid delta type approach. Deliveries to Southern California under the range of equally likely scenarios are summarized in table ES-3.

Table ES-2.—Median Projected Change across Demand and Management Scenarios

| Future Time Period and Scenario | 1.0 MAF Shortage Volume | 1.5 MAF Shortage Volume | Shortage to Lower Basin States | Lake Mead Elevation below 1,000 ft |
|---|---|---|---|---|
| 2020s no action | +29% to +32% | +35 % to 37% | 0.30 MAF | +22% to +25% |
| 2020s Interim Operating Guidelines | +25% to +27% | +73% to +84% | 0.25 MAF | +23% to +26% |
| 2050s no action | +73% to +83% | +74% to +84% | 1.0 MAF | +32% to +42% |
| 2050s Interim Operating Guidelines | +53% to +60% | +62% to +68% | 0.4 MAF | +49% to +56% |

*Notes:* Ranges are representative of project change across all considered demand and management scenarios.

Table ES-3.—Range of Projected Changes in Deliveries via the Banks Pumping Plan

| Future Time Period | Range of Projected Changes in Deliveries via the Banks Pumping Plan |
|---|---|
| 2020s | -28% to +9% |
| 2050s | -27% to +13% |

*Notes:* Ranges are representative of project change across all considered climate change scenarios for the current trend socioeconomic demand scenario.

## Additional Analyses for the Basin Study

To support other Basin Study tasks, reservoir inflows are needed as inputs for a countywide water planning model called CWASim. This model will be used to evaluate structural and non-structural alternatives for meeting future water supply demand under different climate change scenarios. The ensemble informed delta method was used to develop monthly streamflow change factors that are representative of projected mean changes in streamflow across a range of projected precipitation and temperature change. Streamflow change factors were computed from VIC model simulations using CMIP5 climate projections and were applied to the historical reservoir inflows. Table ES-4 summarizes the range of projected annual changes for San Vicente Reservoir inflows as an example of results.

Table ES-4.—Summary of Projected Inflows to San Vicente Reservoir for a Range of Climate Change Scenarios

| **Future Time Period** | **Range of Projected Change in Annual Inflow to San Vicente Reservoir** |
|---|---|
| 2020s | -21% to +46% |
| 2050s | -28% to +42% |

*Notes:* Ranges are representative of project change across all considered climate change scenarios with no alternative management scenarios in place.

In addition to reservoir inflows, the planning model requires outdoor water demands. Precipitation and temperature change factors at representative locations for each of the SDC Water Authority's member agencies were found for the five climate change scenarios and two future periods. These change factors will be used to calculate the required outdoor water demands using a stand-alone spreadsheet calculator as part of a subsequent task in the Basin Study.

# 1. Introduction

The SDC Water Authority provides wholesale water to 24 member agencies in San Diego County The region is dependent on imported water supply to meet 80% of existing demand (City of San Diego et al. 2013; San Diego County Water Authority 2014; Bureau of Reclamation and City of San Diego 2014). Local surface water, groundwater, recycled water, and desalination comprise the remaining 20% of the total water supply portfolio. There is specific interest in SDC Water Authority member agencies developing local water supply sources to offset the need for imported water supplies. Future reliability of imported water is uncertain due to the impacts of climate change, drought and environmental regulation.

## 1.1 Study Purpose and Objectives

The SDC Water Authority and the Bureau of Reclamation (Reclamation) partnered in the San Diego Watershed Basin Study (Basin Study), which identifies and evaluates current and future imbalances in water supply and demand and explores alternatives for addressing future water management challenges. This Basin Study was conducted as part of Reclamation's Basin Studies Program as a means of fulfilling obligations outlined in the SECURE Water Act of 2009 (Science and Engineering to Comprehensively Understand and Responsibly Enhance, Public Law [P.L.] 111-11) and Interior's Sustain and Manage America's Resources for Tomorrow (WaterSMART) Program.

This Basin Study follows an established framework for all basin studies, which includes the following elements:

- Assess current and projected future water supply
- Assess current and projected future water demand
- Evaluate current and projected future system reliability with respect to chosen performance measures
- Identify and evaluate potential adaptation strategies that may reduce any imbalances

To address the elements of the basin study framework, this Basin Study was broken into several specific tasks as shown below:

- Task 1 Project Management
- Task 2.1 Water Supply and Water Demand Projections

- Task 2.2 Downscaled Climate Change and Hydrologic Modeling
- Task 2.3 Existing Structural Response and Operations Guidelines Analysis
- Task 2.4 Structural and Operations Concepts
- Task 2.5 Trade-Off Analysis and Recommendations
- Task 2.6 Final Report

This technical report summarizes analysis for Task 2.2, including evaluating the impact of climate change on historical and projected future water supply through use of climate projections and hydrologic model simulations. Specifically, this report examines the impact of climate change on local and imported water supply sources and offers information for planning future water supply system development in the San Diego watershed. Chapter 2 of this report provides background and methodology for each analysis – impacts to local surface water, impacts to imported water, and development of climate scenarios and inflows for use in the long-term planning model. Chapter 3 presents the results from the local water analysis. Chapter 4 presents results from the imported water analysis, and Chapter 5 summarizes the inflows developed for use in the planning model, Basin Study next steps and how the data developed will be used in other tasks of the Basin Study. Chapter 6 summarizes uncertainties associated with various aspects of the analysis presented in this technical report to the San Diego Watershed Basin Study.

## 1.2 Description of Basin Study Area

The Basin Study area is shown in Figure 1 and contains a majority of San Diego County. This study region coincides with the San Diego Integrated Regional Water Management planning region. Eleven major watersheds comprise this study region. SDC Water Authority provides wholesale water to local water agencies as shown in Figure 1, with water resource features including delivery network and storage shown in Figure 2.

The Basin Study area includes the entire SDC Water Authority service area. The analysis of climate change impacts on water supply is focused on locally available surface and groundwater supply within the study area as well as the two major sources of imported water: the Colorado River and SWP deliveries from the Sacramento and San Joaquin rivers. Local supply analysis examined surface water impacts at storage reservoirs that included Loveland, Barrett, El Capitan, Hodges, Morena, Lower Otay, San Vicente, Sutherland, Sweetwater, and Wohlford (Table 1). These are the major local storage reservoirs in San Diego

County and are the reservoirs included in the county's planning-level model. Groundwater impacts were examined for San Pasqual, San Diego River, and Mission Valley groundwater basins.

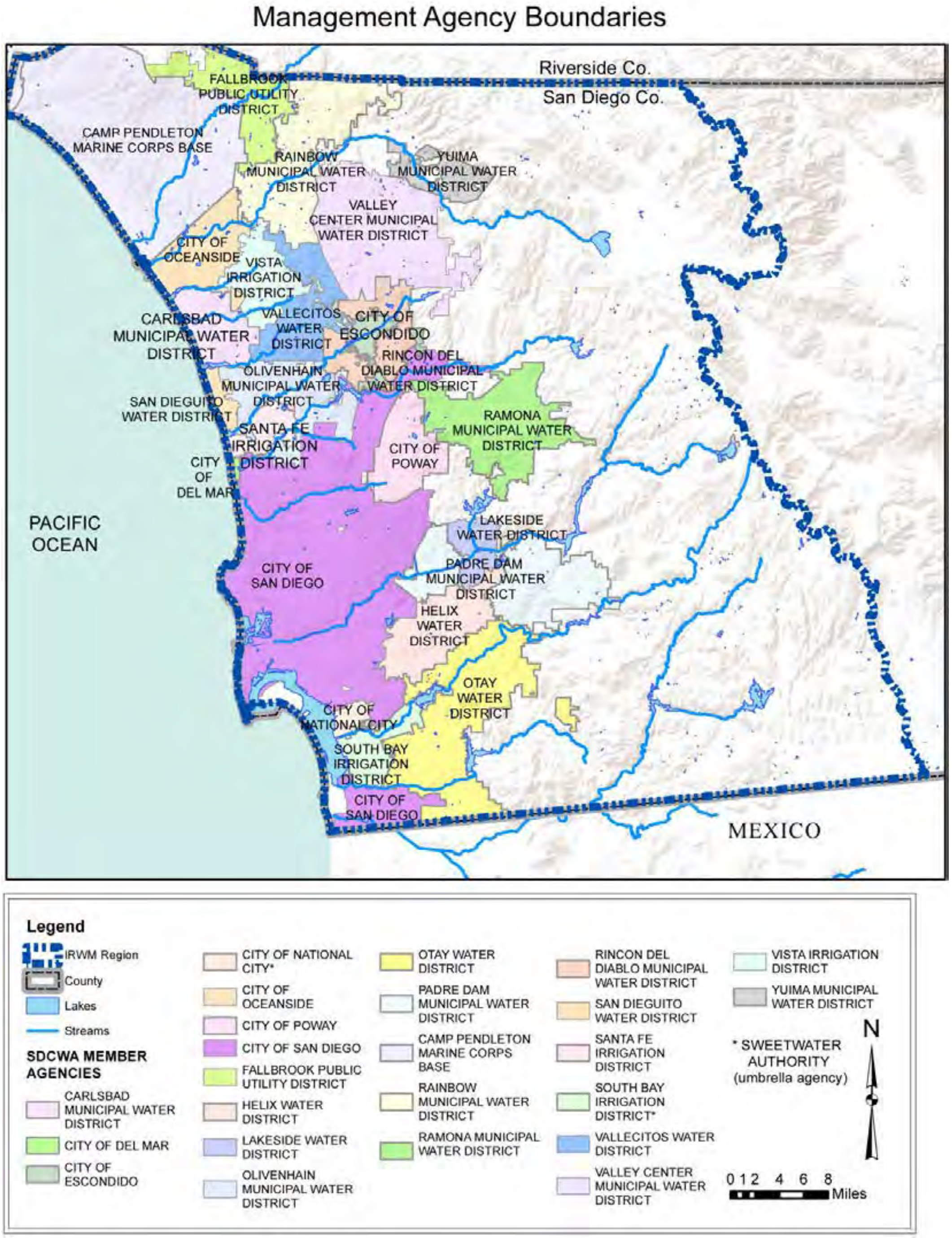

Figure 1.—San Diego watershed basin study management agencies.

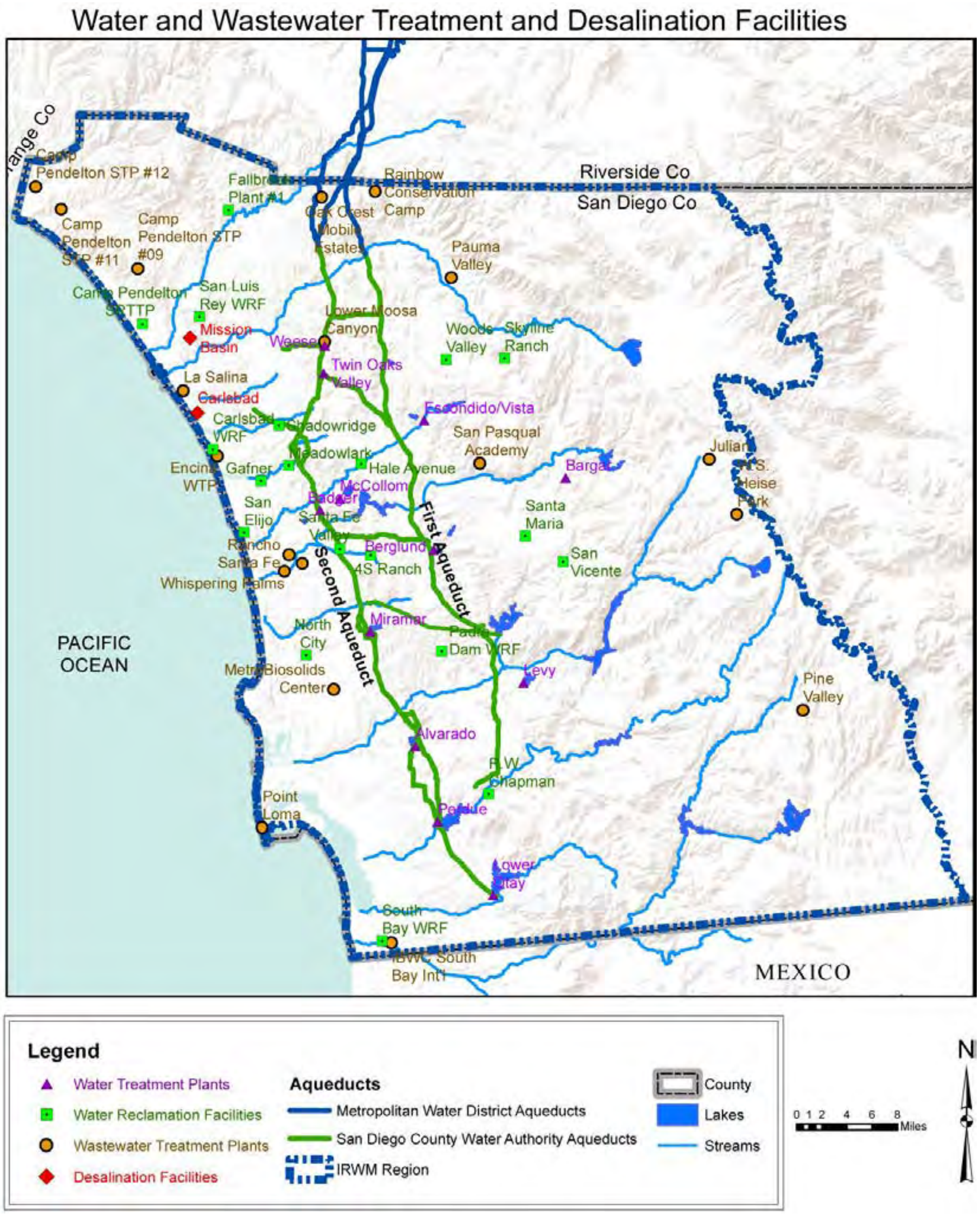

Figure 2.—San Diego Watershed Basin Study water resource features.

Table 1.—San Diego County Local Surface Water Reservoirs (information obtained from San Diego County Water Authority 2014)

| Reservoir | Owner | Storage Capacity (AF) | Average Annual Inflow (AF) |
|---|---|---|---|
| Loveland | Sweetwater Authority | 25,387 | 10,707 |
| Barrett | City of San Diego | 37,947 | 11,656 |
| El Capitan | City of San Diego | 112,807 | 24,414 |
| Hodges | City of San Diego | 30,251 | 25,119 |
| Morena | City of San Diego | 50,207 | 9,672 |
| Lower Otay | City of San Diego | 49,510 | 5,771 |
| San Vicente | City of San Diego; SDC Water Authority | 242,230 | 8,935 |
| Sutherland | City of San Diego | 29,685 | 7,768 |
| Sweetwater | Sweetwater Authority | 28,079 | 4,534 |
| Wohlford | City of Escondido | 6,506 | 1,613 |

# 2. Approaches and Methodology

This chapter describes the approaches and methodology used to support the analysis of climate change impacts, to develop and perform hydrologic model simulations, and to address the goals described in Chapter 1. In this Chapter, Section 2.1 discusses the climate model projections used in the analyses and defines the historical and future periods selected to examine impacts. Section 2.2 describes the approach used for local water supply, including surface water and groundwater. Section 2.3 provides an overview of imported water supply and describes the approach taken in the Basin Study to look at climate change impacts. Finally, Section 2.4 describes the development of climate change scenarios and reservoir inflows for use with the SDC Water Authority long-range planning model.

## 2.1 Climate Change Projections

GCM projections provide estimates of climate states (e.g., precipitation, temperature, etc.) at a coarse spatial resolution (e.g., ~100 km). These climate projections are subsequently downscaled to finer spatial resolutions (e.g., ~10 km) that are suitable for watershed-scale climate change impact studies. For this Basin Study, downscaled projections of precipitation and temperature for the period 1950-2099 were obtained for the CMIP5 (Taylor et al. 2011) experiments. The CMIP5 projections served as the basis for the IPCC Fifth Assessment Report (AR5; Taylor et al. 2011).

GCM simulations over the historical period are constrained by observations of atmospheric and ocean states. For the future period, several alternative scenarios of greenhouse gas (GHG) concentrations are reflected in Representative Concentration Pathways (RCP). This analysis incorporates two RCPs: (i) RCP4.5, which reflects a low-growth or strong emissions controls scenario, and (ii) RCP8.5, which reflects a high-growth and limited emissions control scenario. Use of RCP4.5 and RCP8.5 is consistent with the approach being taken for the current National Climate Assessment (Melillo et al. 2014). In addition to various GHG scenario simulations, many of the simulations for individual GCMs are initialized with different atmosphere and/or ocean climate states in order represent uncertainties stemming from natural low frequency climate variability (Reclamation, 2013).

A downscaled archive of CMIP5 climate and hydrology projections (or DCHP archive) was developed through a collaborative effort between Federal and non-Federal agencies (Reclamation 2013). The projections in the archive were downscaled to 1/8° latitude by 1/8° longitude (~50 square miles) resolution using the Bias-Correction Spatial Disaggregation approach of Wood et al. (2002). These projections are generally termed transient climate projections because they reflect the evolving weather and climate patterns simulated by the GCMs from 1950-2099. For this Basin Study, two future periods were selected to evaluate climate change impacts relative to a reference historical period. The reference historical period and future periods that were selected are summarized in Table 2.

Table 2.—Historical and Future Periods

| | | |
|---|---|---|
| Reference Historical Period | 1990-1999 | 1990s |
| Future Period 1 | 2020-2029 | 2020s |
| Future Period 2 | 2050-2059 | 2050s |

Data for the reference historical period and two future periods were extracted from the DCHP archive for each of the 231 projections. Projected changes in the values across the climate projections are summarized in Chapter 3.

## 2.2 Local Water Supplies

Climate change impacts were assessed separately for local water supplies (surface water and groundwater) and imported water supplies. The following sections discuss how climate change impacts were evaluated for each of these categories of water supply to the region.

### 2.2.1 Precipitation and Temperature

Changes in precipitation and mean temperature were evaluated using downscaled CMIP5 climate for all model grid cells that intersect the Basin Study region. Projected changes in mean annual precipitation and temperature were calculated at each location for the two future periods of interest (2020s and 2050s), relative to the 1990s reference historical period. Changes were estimated separately using projections from both sets of RCPs (i.e. RCP 4.5 and RCP 8.5).

### 2.2.2 Surface Water

SDC Water Authority member agencies maintain local storage and supply systems to ensure reliable delivery of water. Runoff from headwater catchments is the primary local surface water source that is captured in regional storage reservoirs. Evaluating changes in reservoir inflows, along with reservoir outflows and river outlets, can inform regional stakeholders on the impact of climate on surface water supply.

Downscaled CMIP5 climate projections of precipitation, minimum and maximum temperatures, and wind, were used as inputs to the VIC macro-scale hydrology model to generate projections of hydrologic variables such as snowpack, evapotranspiration, and runoff (Liang et al. 1994, Liang et al. 1996; Nijssen et al. 1997). The VIC model simulates surface runoff and baseflow for each grid cell (1/8° spatial resolution in this application). Surface runoff and baseflow are subsequently routed to stream channels to generate streamflow at select locations. Transient model simulation output (1950-2099) using VIC version 4.1.2 were obtained from the DCHP archive (Bureau of Reclamation 2016a) for all model grid cells that intersect the Basin Study region. Streamflow routing was subsequently done at selected streamflow locations identified below (see table 3).

Hydrologic features of interest identified within the study area correspond to important locations for management of the local water resources system. Locations include:

- reservoir inflows
- reservoir outflows
- river outlets
- representative groundwater recharge locations

Select locations for analysis are summarized in figure 3 and listed in table 3. Selected reservoir inflow locations to major water supply reservoirs include those that are discussed in the Integrated Regional Water Management plan and represented in a long-range planning systems model. The SDC Water Authority developed a long-range planning model of the San Diego region's water supply system (CWASim) using the GoldSim® simulation platform, in part to examine water supply and demand under current and future climate. These locations encompass the major tributary flows to the reservoirs. Reservoir outflows represent an integration of contributing reservoir inflow locations. Major river outlet locations that were selected include Otay, Sweetwater, San Diego, and San Dieguito.

For each location, simulated natural streamflow was computed using the approach of Lohmann et al. (1996), based on routing of grid-based VIC model output. This simulated streamflow does not reflect any management or operation within the watershed. For all identified locations, projected changes in mean streamflow were calculated at each location for the two future periods of interest (2020s and 2050s), relative to the 1990s reference historical period. This was done for mean annual streamflow, as well as mean December to March (cool season) and mean April to July (warm season) streamflow. Streamflow changes were estimated separately using projections from both sets of RCPs (i.e. RCP 4.5 and RCP 8.5).

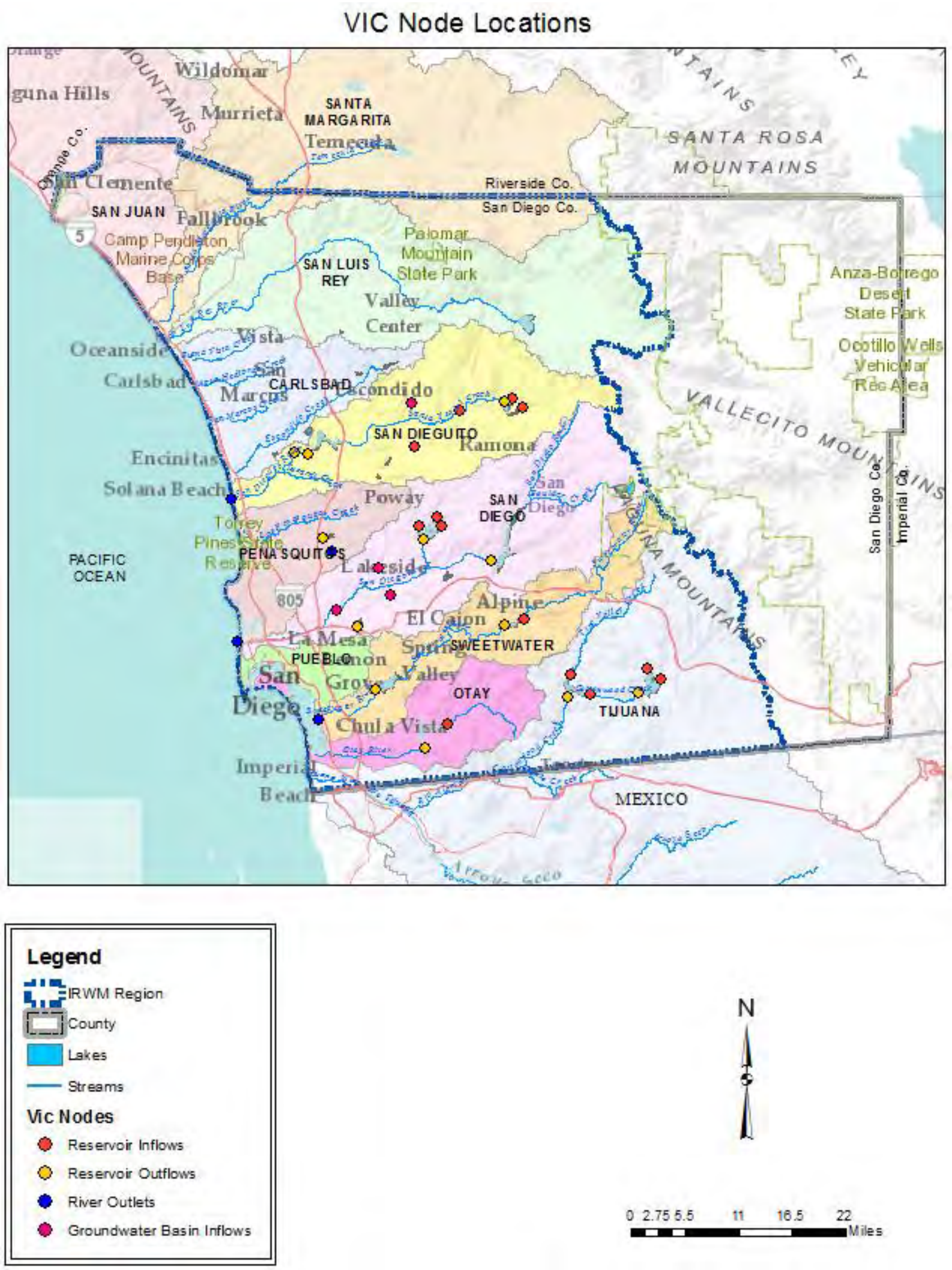

Figure 3.—San Diego County surface water identified locations.

Table 3.—Surface Water Identified Locations

| | Longitude | Latitude | Name | Water Body | Description |
|---|---|---|---|---|---|
| Reservoir Inflows | -116.865 | 33.107 | Santa Ysabel Creek Gauge (11025500) | San Ysabel Creek | Inflow to Hodges |
| | -116.945 | 33.052 | Santa Maria Creek Gauge (11028500) | Santa Maria Creek | Inflow to Hodges |
| | -116.905 | 32.946 | San Vicente Kimball Valley Inflow | San Vicente Reservoir | Inflow to San Vicente |
| | -116.937 | 32.932 | San Vicente Foster Canyon Inflow | San Vicente Reservoir | Inflow to San Vicente |
| | -116.895 | 32.932 | San Vicente Barona Valley Inflow | San Vicente Reservoir | Inflow to San Vicente |
| | -116.883 | 32.638 | Jamul Creek Gauge (11014000) | Jamal Creek | Inflow to Lower Otay |
| | -116.632 | 32.683 | Cottonwood Creek Inflow | Cottonwood Creek | Inflow to Barrett |
| | -116.531 | 32.721 | Morena Creek Inflow | Morena Creek | Inflow to Morena |
| | -116.507 | 32.705 | Cottonwood Creek Inflow | Cottonwood Creek | Inflow to Morena |
| | -116.666 | 32.712 | Pine Valley Inflow | Pine Valley | Inflow to Barrett |
| | -116.750 | 32.794 | Sweetwater River Inflow | Sweetwater River | Inflow to Loveland |
| | -116.772 | 33.125 | Bloomdale Creek Inflow | Bloomdale Creek | Inflow to Sutherland |
| | -116.755 | 33.112 | Santa Ysabel Creek Inflow | Santa Ysabel Creek | Inflow to Sutherland |
| Reservoir Outflows | -117.135 | 33.040 | Lake Hodges Dam Gauge | Hodges Reservoir | Outflow from Hodges |
| | -116.671 | 32.679 | Barrett Lake Dam | Cottonwood Creek | Outflow from Barrett |
| | -116.547 | 32.686 | Morena Dam | Cottonwood Creek | Outflow from Morena |
| | -116.785 | 32.785 | Sweetwater Falls Dam | Sweetwater River | Outflow from Loveland |
| | -117.011 | 32.689 | Sweetwater Dam | Sweetwater River | Outflow from Sweetwater |
| | -116.924 | 32.602 | Savage Dam | Otay River | Outflow from Lower Otay |
| | -117.045 | 32.781 | Murray Reservoir Dam | Murray Reservoir | Outflow from Murray Reservoir |
| | -117.107 | 32.914 | Miramar Lake Dam | Miramar Lake | Outflow from Miramar Lake |
| | -116.787 | 33.119 | Sutherland Lake Dam | Santa Ysabel Creek | Outflow from Sutherland |
| | -116.927 | 32.913 | San Vicente Dam (11022100) | San Vicente Reservoir | San Vicente Reservoir Level |
| | -116.808 | 32.882 | El Capitan Reservoir (11020600) | El Capitan Reservoir | El Capitan Reservoir Level |

| | Longitude | Latitude | Name | Water Body | Description |
|---|---|---|---|---|---|
| **River Outlets** | -117.157 | 33.040 | San Dieguito River Gauge | San Dieguito River | Downstream of Hodges |
| | -117.255 | 32.757 | San Diego River Outlet | San Diego River | Outlet to Ocean |
| | -117.111 | 32.643 | Sweetwater River Outlet | Sweetwater River | Outlet to Ocean |
| | -117.090 | 32.893 | Otay River Outlet | Otay River | Outlet to Ocean |
| | -117.269 | 32.972 | San Dieguito River Outlet | San Dieguito River | Outlet to Ocean |

Table 4.—Representative Groundwater Selected Locations

| | Longitude | Latitude | Name | Water Body | Description |
|---|---|---|---|---|---|
| **Groundwater Basin Inflows** | -117.081 | 32.807 | Mission Valley GW Basin San Diego River Inflow | San Diego River | Mission Valley GW Basin Inflow |
| | -116.985 | 32.830 | San Diego GW Basin Forester Creek Inflow | Forester Creek | San Diego GW Basin Inflow |
| | -117.006 | 32.870 | San Diego GW Basin Sycamore Canyon Inflow | Sycamore Canyon | San Diego GW Basin Inflow |
| | -116.952 | 33.116 | San Pasqual GW Basin Guejito Creek Inflow | Guejito Creek | San Pasqual GW Basin Inflow |

### 2.2.3 Groundwater

Groundwater supplies are used to meet approximately 4% of total SDC Water Authority member agencies' water demand. Streamflow is the primary source of groundwater recharge for basins in San Diego County, with additional recharge from precipitation, wastewater treatment outflows (effluent), and agricultural return flows. Given the relationship between streamflow and groundwater recharge, changes in streamflow where it enters the groundwater basin was used to quantify the impact of climate change on groundwater.

Groundwater basins identified by Basin Study partners as being of particular interest are the San Pasqual, the San Diego River, and Mission Valley basins (refer to figure 9). California Department of Water Resources (CA DWR) Bulletin 118 provides background information on these three groundwater basins, including composition and primary sources of recharge (Bulletin 118 Update 2003; California Department of Water Resources 2003). San Pasqual Valley Groundwater Basin in central San Diego County is fed primarily by recharge from precipitation and ephemeral streams. Typical years see complete infiltration of precipitation with no streamflow leaving the valley. Recharge into the San Diego River Valley Groundwater Basin primarily comes from releases into San Vicente Creek and the San Diego River from San Vicente and El Capitan dams, respectively, as well as underflow from both reservoirs. Several smaller tributaries also contribute to recharge. Mission Valley Groundwater Basin, which is adjacent to the San Diego River Valley Basin, receives a majority of its recharge from the San Diego River. A smaller fraction of recharge comes from irrigation return flows (San Pasqual), wastewater discharge, and rainfall.

Representative groundwater recharge locations, where these channels enter the groundwater basins, were identified and used to examine climate change impacts indirectly through changes in surface runoff. Projected changes in streamflow were used as a proxy to project changes in groundwater recharge. Selected locations are listed in table 4 (above) and illustrated in figure 3.

For all identified locations, projected changes in mean streamflow were calculated at each location for the two future periods of interest (2020s and 2050s), relative to the 1990s reference historical period. This was done for mean annual streamflow as well as mean December to March (cool season), and mean April to July (warm season) streamflow. Streamflow changes were estimated using projections from both sets of RCPs, i.e. RCP 4.5 and RCP 8.5.

## 2.3 Imported Water Analyses

The SDC Water Authority currently relies on imported water to meet 80% of its demand. Imported water is delivered from two main sources: the Colorado River and SWP. Background on these two sources of imported water is provided in Sections 2.3.1 and 2.3.2. The approach for evaluating historical and projected future changes in imported water to the San Diego region from these two sources relies on results from two existing studies, namely the Colorado River Basin Water Supply and Demand Study (CRB Water Supply and Demand Study; Reclamation 2012a) and the Sacramento and San Joaquin Basin Study (SSJ Basin Study; Reclamation 2016b). Both studies examined the impact of climate change on imported water supplies, and each developed its own set of future climate scenarios. The CRB Water Supply and Demand Study used scenarios based on the Coupled Model Intercomparison Project Phase 3 (CMIP3) (Meehl et al. 2007) climate projections, as opposed to the CMIP5 projections. The CMIP3 projections correspond with future development storylines defined by the Special Report on Emissions Scenarios (SRES) scenarios, with B1, A1B, and A2 being the most commonly used in impacts studies (Nakicenovic et al. 2000).

Figure 4 shows the comparison between the three SRES scenarios and the CMIP5 RCP scenarios that were used for the analysis of local water supplies. There is a greater range in future global warming by 2100 in the CMIP5 emissions scenarios; however, for the 2050s Basin Study future time horizon, the range is comparable to CMIP3. RCP4.5 and SRES A2 have similar warming by 2050. RCP8.5 has a slightly higher degree of global warming than A2 by 2050.

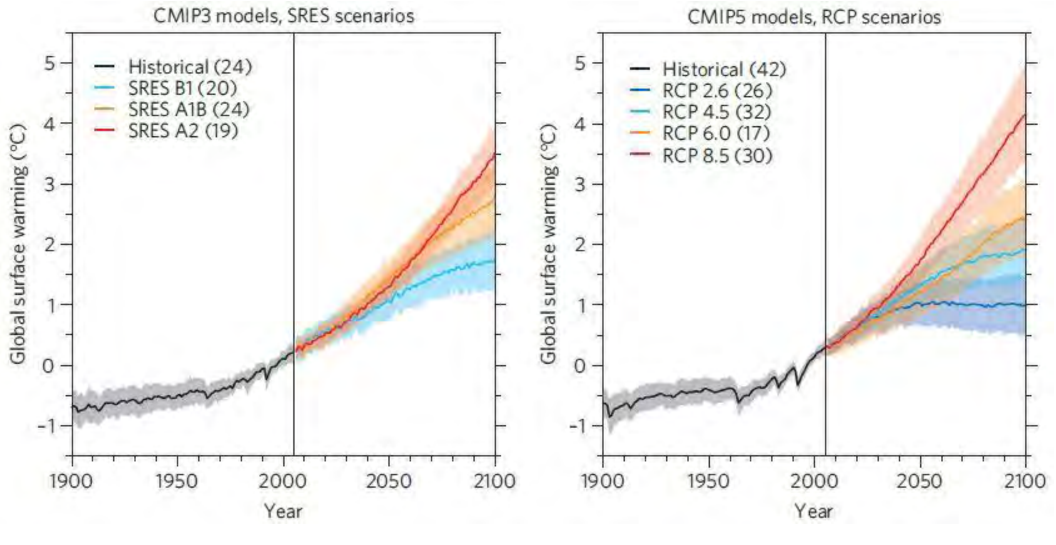

Figure 4.—CMIP3 and CMIP5 climate projection scenarios of temperature (Knutti and Sedláček 2012).

In the SSJ Basin Study five climate change scenarios were developed using a version of the ensemble hybrid delta (HDe) approach with a combined set of CMIP3 and CMIP5 projections. Additional information about the development

and selection of the socioeconomic and climate change scenarios can be found in the SSJ Basin Study report (Bureau of Reclamation 2016b).
The CRB Water Supply and Demand Study and the SSJ Basin Study evaluate the ability of the Colorado River and SWP to deliver water using several selected performance measures. Performances measures from the CRB Water Supply and Demand Study that are relevant to this Basin Study include Lake Mead reservoir levels and shortages to Lower Basin States (California, Arizona, and Nevada). Technical Report D – System Reliability Metrics (Bureau of Reclamation 2012b) describes the development and rational behind the selection of these measures.

The performance measure from the SSJ Basin Study that is most relevant to this Basin Study is the export volume from the SWP to southern California. Given the legal structure and regulations used to allocate water from each of these sources, and periodic modification of the legal structure and regulations, it is difficult to determine exact future allocations to SDC Water Authority.

Raw values of projections were obtained from each basin study – shortages and reservoir levels from the CRB Water Supply and Demand Study and SWP exports from the SSJ Basin Study. These raw values were used to recalculate the performance measures described for the two future periods used in this Basin Study. The approach taken for each measure is described below.

### 2.3.1 Colorado River

The ‘Law of the River’ apportions Colorado River water among the seven Colorado River Basin States, and the Seven Party Agreement apportions California’s Colorado River allocation among California water users. The Metropolitan Water District of Southern California (MWD), of which the SDC Water Authority is a member agency, has priority to 1,202,000 acre-feet per year of Colorado River water, including 112,000 acre-feet specifically identified for use by the City and County of San Diego. The State of California, in their Colorado River Water Use Plan, commonly referred to as the ‘4.4 Plan’ (California 2000), along with the 2003 Colorado River Quantification Settlement Agreement (QSA), modified the Seven Party Agreement to ensure California remains within the 4,400,000 acre-feet allocation specified in the Colorado River Compact. It has done so by setting new apportionments for irrigation districts. It also established water transfers from the Imperial Irrigation District (IID) to the SDC Water Authority. This water transferred from IID originates in the Colorado River, but given the QSA mandate to supply water to California, it should be considered separate from the Colorado River imported water. Also included in the QSA is the All-American and Coachella Valley Canal Linings Projects by which the SDC Water Authority paid for canal lining in exchange for the conserved water. The SDC Water Authority is guaranteed at least 77,000 acre-feet per year, and up to an additional 4,850 acre-feet based on water required for environmental use. As with the IID transfer, while this water originates in the Colorado River, it is guaranteed to the SDC Water Authority as part of the QSA.

The CRB Water Supply and Demand Study was completed under the Department of the Interior’s WaterSMART program, with the final report issued in 2013. The impact of a changing climate, changing demand, and changing operations were considered and evaluated according to a set of performance measures which included reservoir levels and deliveries to water right holders. The study region included the entire Colorado River basin watershed as well as adjacent areas receiving Colorado River water. The identified performance measures indicated how well the Colorado River system functioned under different future conditions and served as a basis for evaluating different structural and non-structural alternatives. For this Basin Study, we selected four performance measures from the CRB Water Supply and Demand Study that are relevant to the study region. Selected performance measures include:

- Lower Basin shortage volume of 1.5 MAF in 5 years
- Lower Basin shortage volume of 1.0 MAF in 2 years
- Lake Mead elevation threshold (1000 ft elevation, or 4.5 MAF storage volume)
- Mean annual shortages to Lower Basin States

The first measure is defined as the percentage of traces exceeding 1.5 MAF shortage volume to the Lower Basin at least once in any five year window. Similarly, the second measure is defined as the percentage of traces exceeding 1 MAF shortage volume to the Lower Basin at least once in any two year window. These measures were computed for all transient projections (1950-2099 time period) evaluated for the CRB Water Supply and Demand Study. Many sequences, or traces of future hydrology, were run for each demand and operations scenario, with the percent of traces exceeding the shortage thresholds, or showing reservoir levels below the threshold reported. The shortage volumes, 1.5 MAF and 1 MAF were chosen in the CRB Water Supply and Demand Study through an iterative process with stakeholders. The 1,000ft Lake Mead level (which is associated with storage of about 4.5 MAF) is directly tied to operations in the 2007 Interim Operating Guidelines. When Lake Mead is projected to fall below this level, the Secretary of the Interior consults with Lower Basin States to discuss further measures. The raw transient projection data were used to calculate the performance measures for the two future periods used in the Basin Study. A moving window for the two lower basin shortage volumes was used to find the frequency of occurrence of shortage in the 2020s and 2050s. The frequency of occurrence of Lake Mead falling below 1000 ft for the two future periods, and the mean annual shortage to Lower Basin States were also calculated from these data.

The performance measures were evaluated under six demand scenarios representing potential futures, given sets of driving forces. The six scenarios are described in Table 5.

Table 5.—Colorado River Basin Study Demand Scenarios

| Scenario | Description |
|---|---|
| A | Continuation of growth, development patterns and institutions follow long-term trends |
| B | Slow growth with emphasis on economic efficiency |
| C1 | Economic resurgence (population and energy) and current preference toward human and environmental values |
| C2 | |
| D1 | Expanded environmental awareness and stewardship with growing economy |
| D2 | |

Two sets of operations were also considered by the CRB Water Supply and Demand Study, namely continuation of the 2007 Interim Operating Guidelines (US Department of the Interior 2007) beyond 2026, and the no-action alternative from the interim guideline Environmental Impact Statement (Reclamation 2007). The 2007 Interim Operating Guidelines establish coordinated operations in years when shortage conditions are declared for the Lower Basin States. Prior to the establishment of these guidelines, no detailed regulations and operations criteria existed for water supply shortages. This provides Lower Basin States with more certainty in annual water deliveries, especially in years of drought. The guidelines are currently in place until 2026. The no-action alternative reflects the operational guidelines in place prior to 2007. In 2012, Minute 319 updated the Colorado River treaty with Mexico, allowing for joint cooperative actions including altered operations when Lake Mead conditions are low and temporary storage of Mexico's water. These altered operations are not reflected in the CRB Water Supply and Demand Study results.

### 2.3.2 State Water Project

The CA DWR sets allocations from the SWP based on operational studies that account for current and projected hydrologic conditions, reservoir storage, operational constraints including Biological Opinions for delta smelt, salmonids, and longfin smelt, and total contractor requests. Hydrologic conditions for the Sacramento and San Joaquin Rivers are determined using Water Supply Index (WSI) forecasts for each river. WSI are classified wet, above normal, below normal, dry, or critical based on thresholds established in the 1995 State Water Resources Control Board Water Quality Control Plan. MWD is currently entitled to a maximum of 1,911,500 acre-feet annually through 2035 in the 2005 contract with CA DWR. The SWP exports water at the Harvey O. Banks Pumping Plant (Banks). Banks exports were evaluated under several socioeconomic and climate change scenarios as part of the SSJ Basin Study. These data were used to examine volumes and changes in exports for the 2020s and 2050s future periods selected for this Basin Study. Three socioeconomic scenarios were considered:

- **Expanded Growth (EG).—**This scenario assumes a high population growth rate and a low urban density, expanding urban development and land use.

- **Current Trends (CT).—**This scenario was used as a baseline for comparison and projects the trend on current population growth and land use changes. The CA Department of Finance population projections which go from present day to 2050 were extended to the end of the century.

- **Slow Growth (SG).—**This scenario assumes a low population growth rate and a high urban density, slowing the rate of urban expansion.

## 2.4 Analysis to Inform Long Term Planning Model

For inflows to the reservoirs outlined in table 1, a version of the ensemble-informed delta method (Bureau of Reclamation 2014) was used to develop climate change scenario inputs for the CWASim long term planning model. Mean annual changes in precipitation (in percent) and temperature (in degrees Fahrenheit), were calculated between the 1990-1999 historical period and the 2020s (2020-2029) and 2050s (2050-2059) future periods for all models and RCPs in the CMIP5 archive (refer to figure 5). The 10th, 50th, and 90th percentile values were calculated for temperature change and precipitation change and used to group the CMIP5 projections into five climate change scenarios as shown in Table 6. The 10 CMIP5 projections closest to the percentile intersections were used to inform to each climate change scenario.

VIC model simulations of natural streamflow for each of the selected groupings of projections were used to compute monthly streamflow change factors for developing climate adjusted CWASim inputs. For each of the future time periods (2020s and 2050s), the mean change in streamflow across the 10 projections was computed, resulting in one change factor per month (e.g January), per scenario (e.g. hot-dry), and per time period (e.g. 2020s). Monthly streamflow change factors were then applied to historical CWASim inputs to develop climate adjusted streamflow inputs for the long term planning model.

Table 6.—Ensemble Informed Delta Scenario Definitions

| **Scenario** | **Temperature Change (°F)** | **Precipitation Change (%)** |
|---|---|---|
| hot-dry | 90th percentile | 10th percentile |
| hot-wet | 90th percentile | 90th percentile |
| middle | 50th percentile | 50th percentile |
| warm-dry | 10th percentile | 10th percentile |
| warm-wet | 10th percentile | 90th percentile |

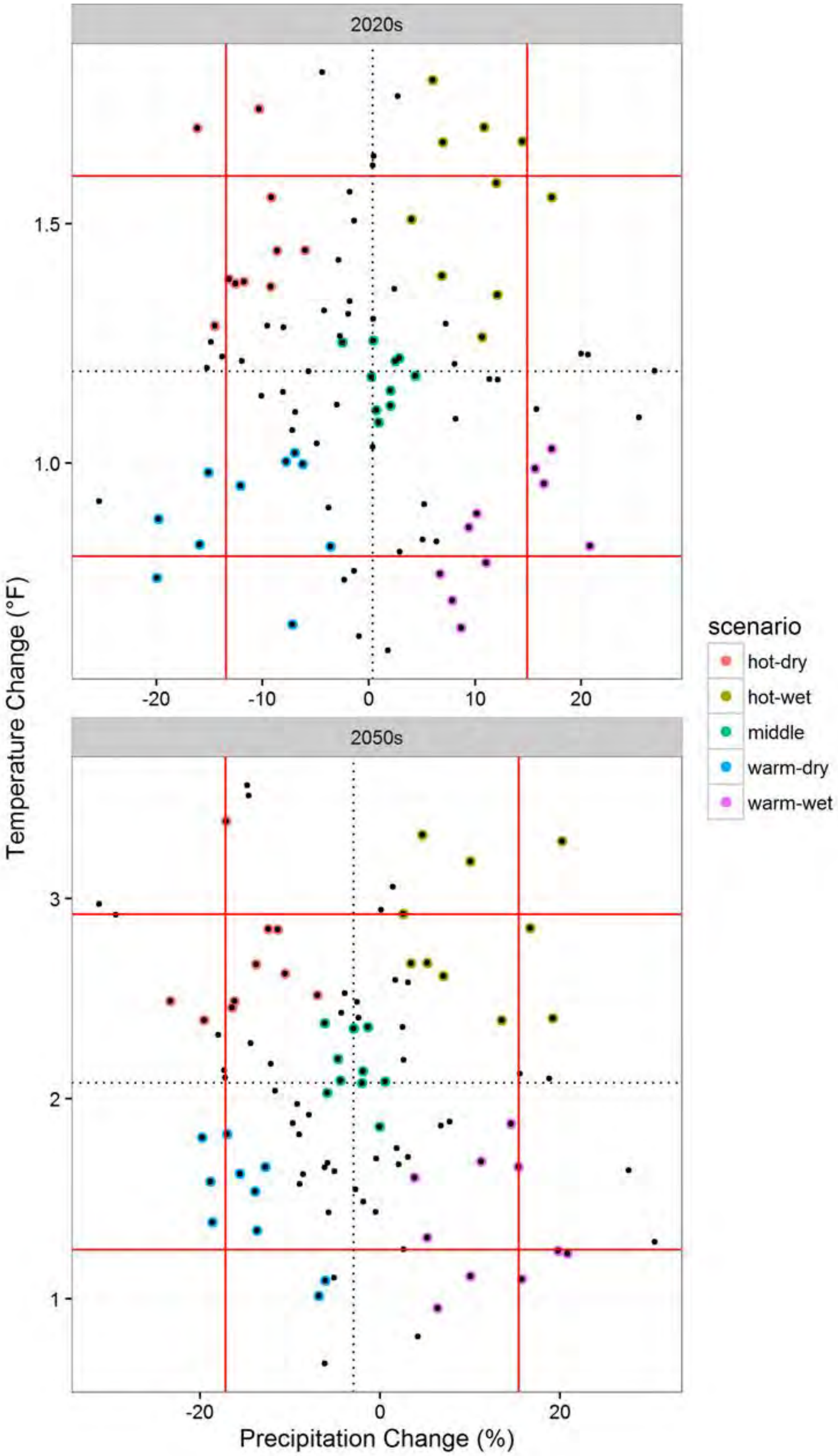

Figure 5.—Ensemble informed delta climate change scenarios.

# 3. Assessment of Local Water Supplies

Local surface water and groundwater made up 14% of SDC Water Authority's supply in 2013 (San Diego County Water Authority 2014). Climate change impacts on surface water and groundwater locations were evaluated using the approach described in Section 2.2.

## 3.1 Precipitation and Temperature

Projections of precipitation and temperature were obtained from the CMIP5 DCHP archive discussed in Section 2.2.1. Projected change for the two future periods compared with the reference historical baseline for model grid cells that intersect the Basin Study region are presented below. Figure 6 illustrate the median projected precipitation change as a percent, based on the full suite of transient projections. Across San Diego County, annual precipitation increases by a range of 2% to 8% under RCP4.5 and increases by 1% to 3% under RCP8.5 in the 2020s future period. There is a broader range of projected change in the 2050s future period, ranging from no change to a 10% increase under RCP4.5 and ranging from no change to a 12% increase under RCP8.5.

Figure 7 illustrates the median projected temperature change in degrees Fahrenheit. Across San Diego County, annual temperature increases by a range of 1.5 to 1.8 degrees Fahrenheit under RCP4.5 and a range of 1.8 to 1.9 degrees Fahrenheit under RCP8.5 in the 2020s future period. In the 2050s future period even greater increases in temperature are seen, with a range of 3 to 3.4 degrees Fahrenheit under RCP4.5 and increases of 4.2 to 4.5 degrees under RCP8.5.

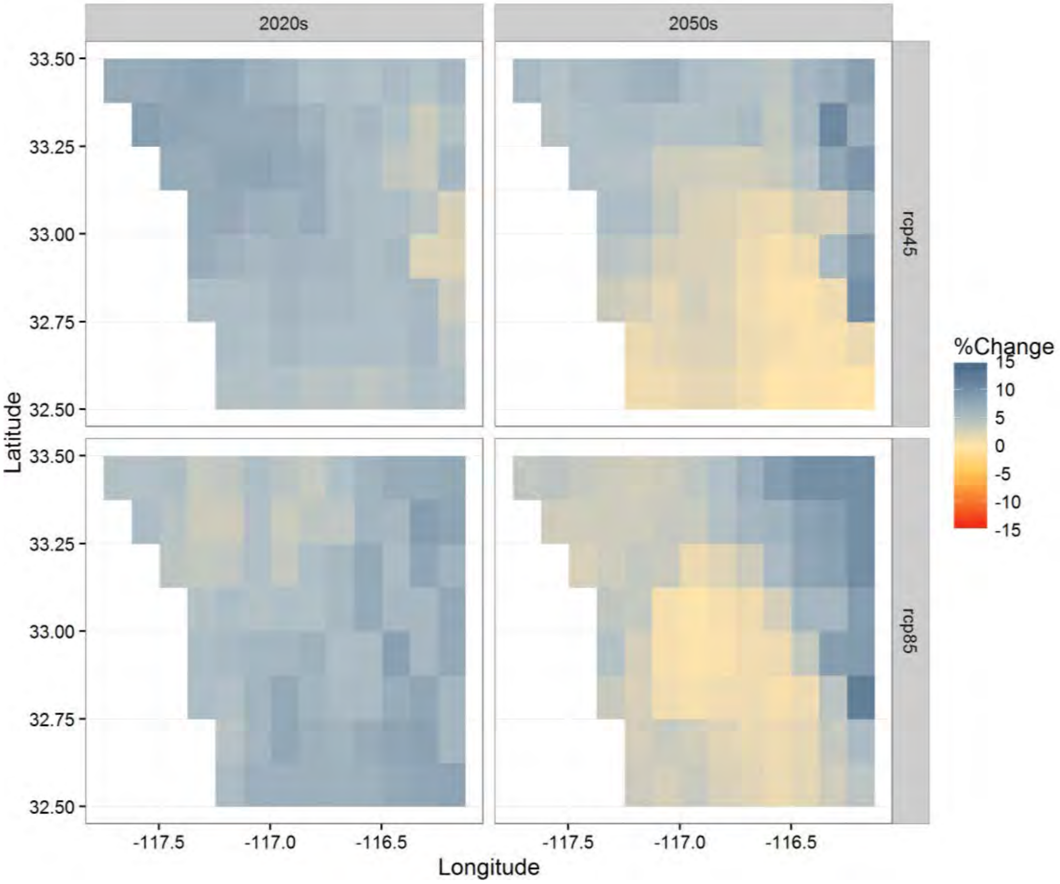

Figure 6.—San Diego County mean annual precipitation change.

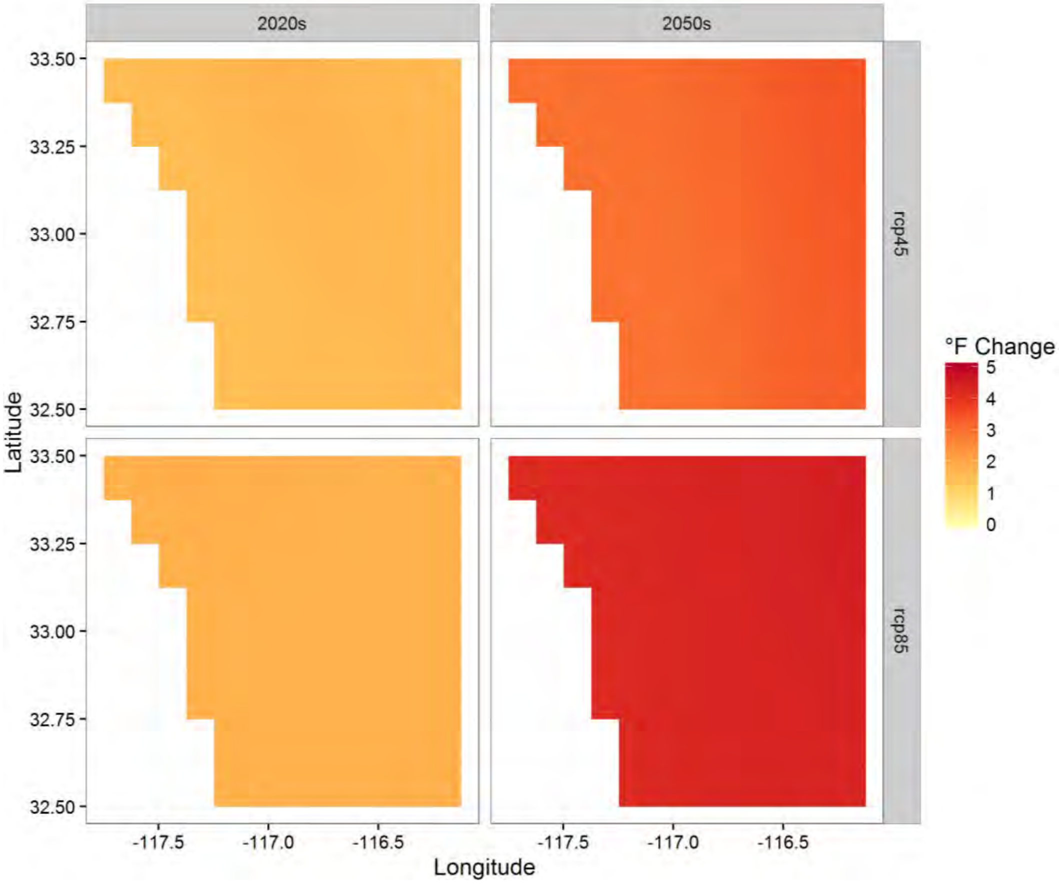

Figure 7.—San Diego County mean annual temperature change.

## 3.2 Surface Water

Simulated natural flow values were obtained from VIC modeling as described in Section 2.2.1. Results for selected locations are presented below. Additional figures for other locations can be found in Appendix A. Projected changes in annual and seasonal streamflow for three tributaries to San Vicente Dam (Barona Valley, Foster Canyon, and Kimball Canyon) are shown in Figure 8, Figure 9, and Figure 10, respectively. Similarly, project streamflow at the San Vicente Dam outflow location is shown in figure 11. Projected changes in seasonal streamflow are represented by cool season flows (defined as December through March) and warm season flows (defined as April through July).

Figures 8 through 11 illustrate the median projected change as a percent, based on the full suite of transient CMIP5 projections of natural (unimpaired) streamflow discussed in Section 2.2.2. These three inflow locations to San Vicente Dam see increases in annual streamflow by a range of 7% to 9% under RCP4.5 and increases of 15% to 22% under RCP8.5 in the 2020s future period. These increases are also seen in the December to March streamflow, namely 11% to 12% under RCP4.5 and 25% to 26% under RCP8.5. April to July streamflows see more modest increases in the 2020s, 5% to 7% under RCP4.5 and 9% to 19% under RCP8.5. In the 2050s future period, these increases in streamflow are even greater under RCP4.5 for the annual and December to March periods, with smaller increases seen for the April to July period. Under RCP8.5 streamflow increases in the 2050s are smaller than the 2020s under RCP8.5 for the annual and December to March periods, with decreases seen in the April to July period. Similar changes in streamflow are seen at all three inflow locations and at the San Vicente Dam outflow location.

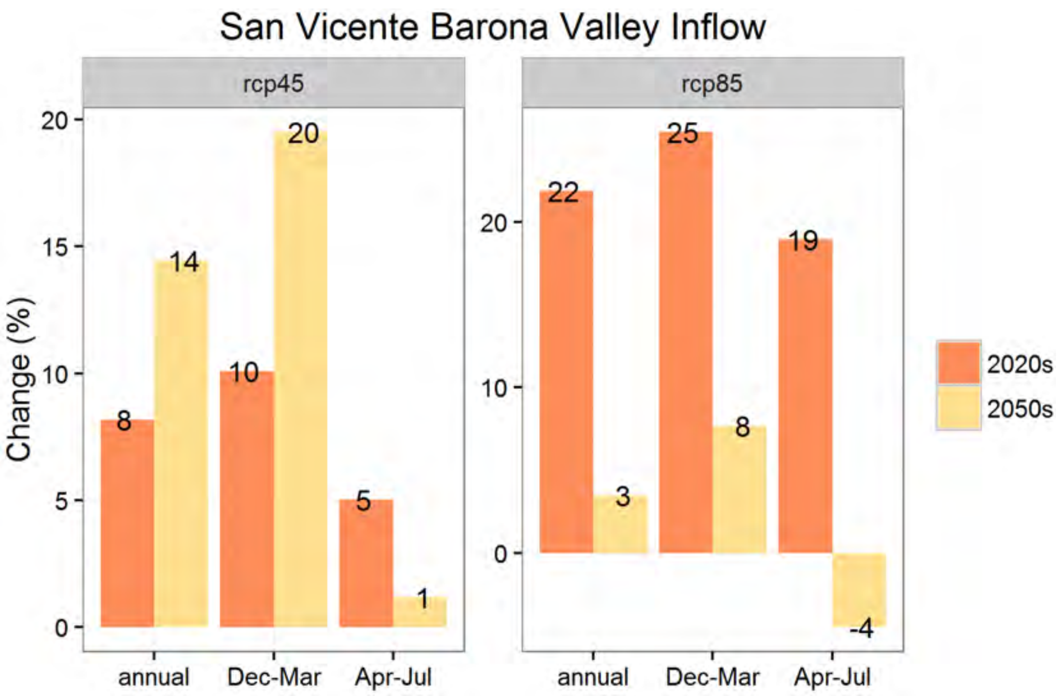

Figure 8.—San Vicente Barona Valley inflow change.

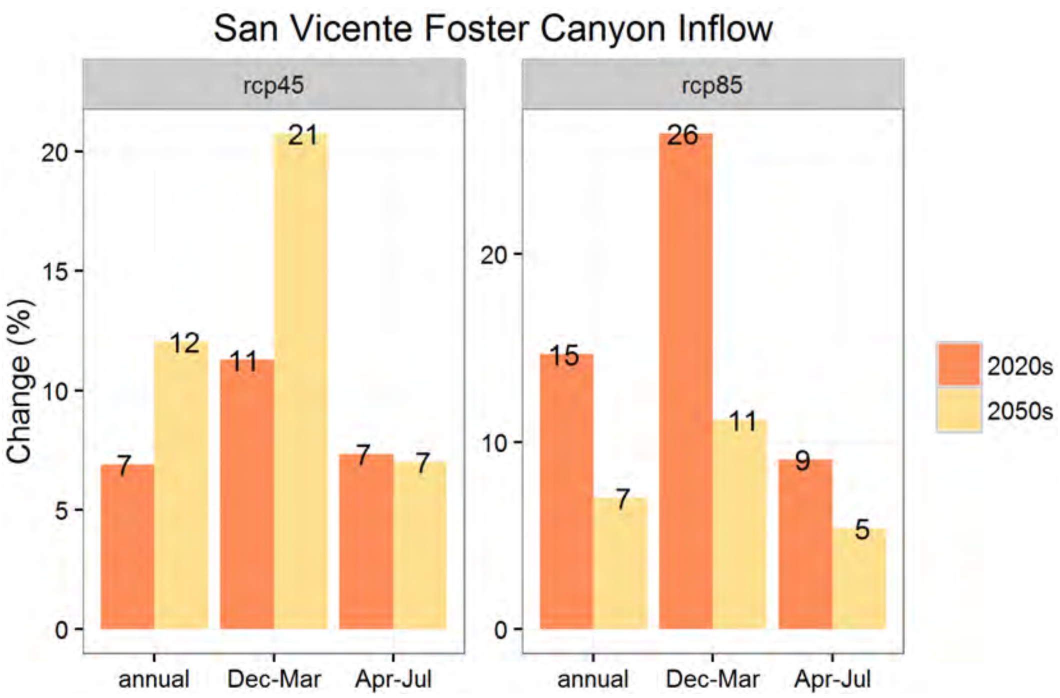

Figure 9.—San Vicente Foster Canyon inflow change.

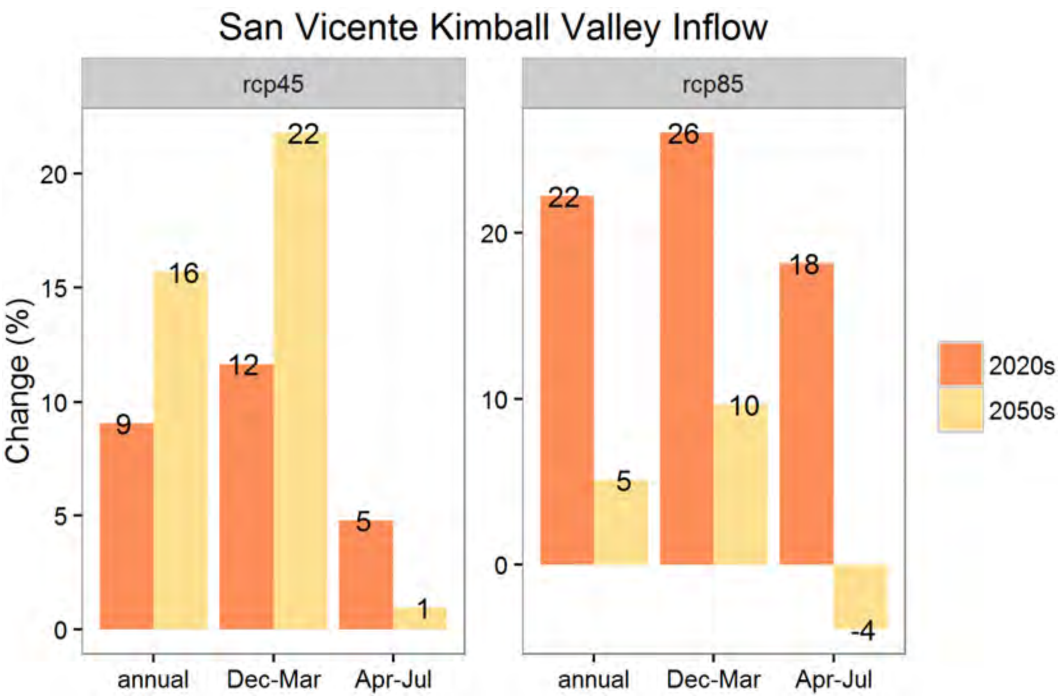

Figure 10.—San Vicente Kimball Valley inflow change.

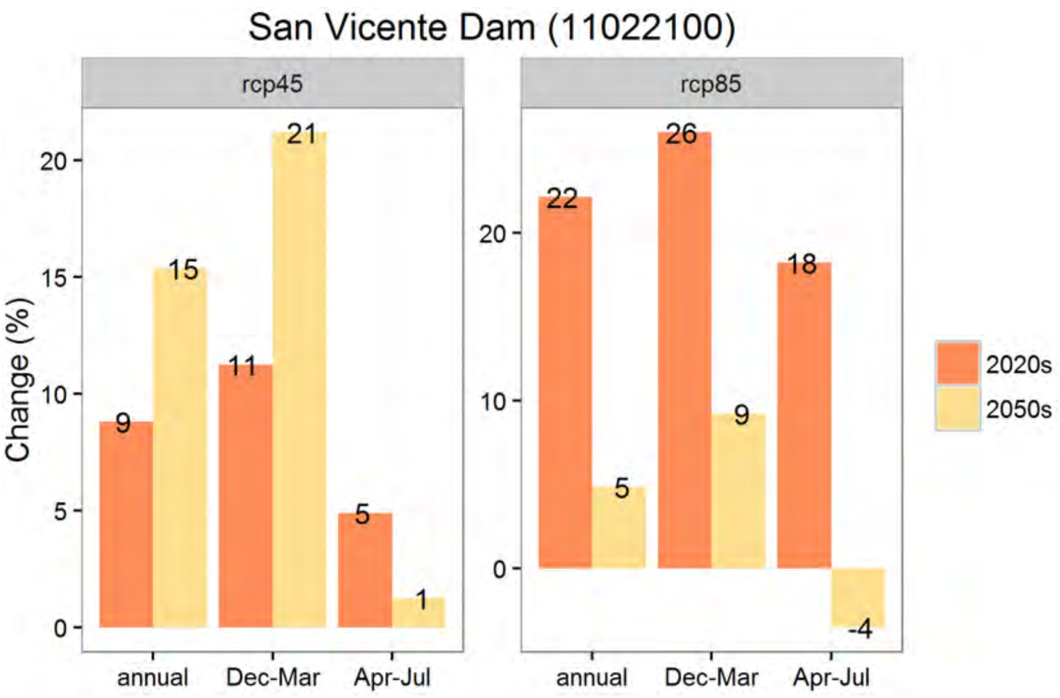

Figure 11.—San Vicente Dam streamflow change.

## 3.3 Groundwater

For the three groundwater basins evaluated as part of this study, namely the Mission Valley Groundwater Basin, the San Diego Groundwater Basin, and the San Pasqual Groundwater Basin, projected future changes are similar to projections of surface water. Projected change in annual and seasonal streamflow at these groundwater locations are summarized in figure 12 through figure 15. A similar pattern to the surface water locations is seen where annual increases for the 2020s are greater under RCP8.5, ranging from 16% to 24%. For the same period, annual increases under RCP4.5 range from 4% to 12%. By the 2050s, higher increases are seen under RCP4.5, from 10% to 19%, than under RCP8.5, from 3% to 8%. December to March shows higher increases than annual flows for all locations, with slight increases or decreases in streamflow seen in the April to July period.

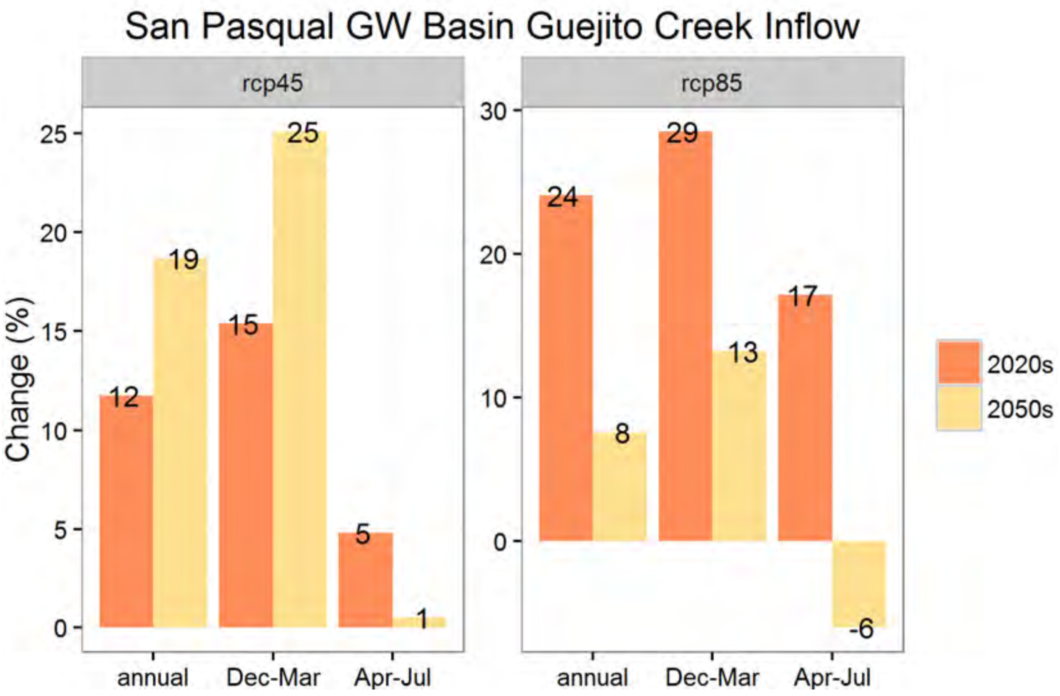

Figure 12.—San Pasqual Groundwater Basin Guejito Creek streamflow recharge.

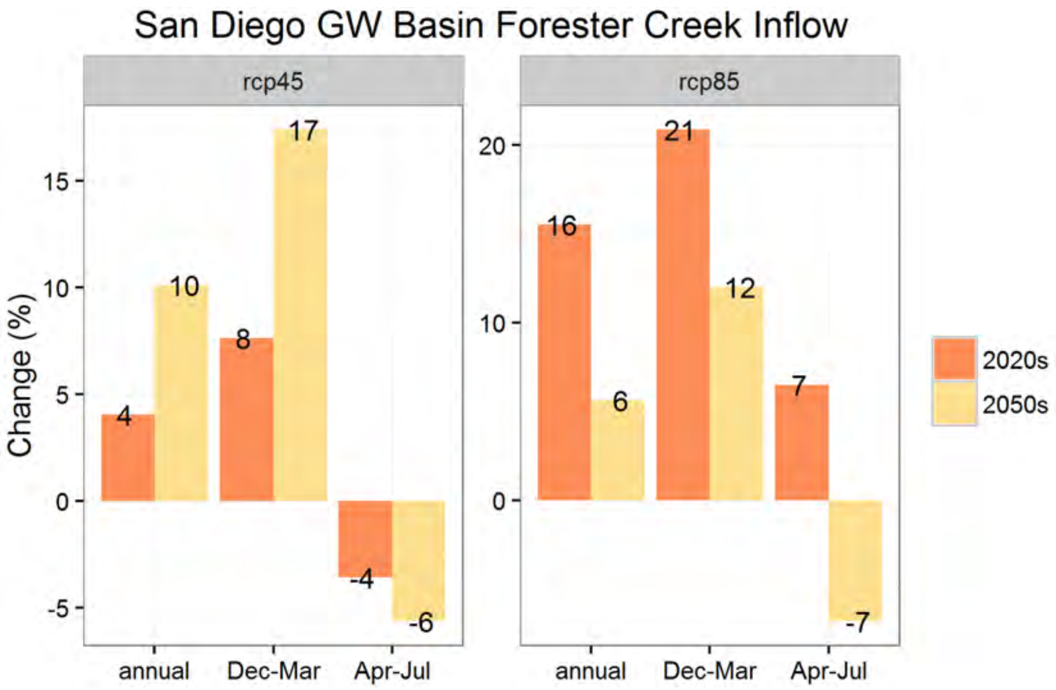

Figure 13.—San Diego River Groundwater Basin Forester Creek streamflow recharge.

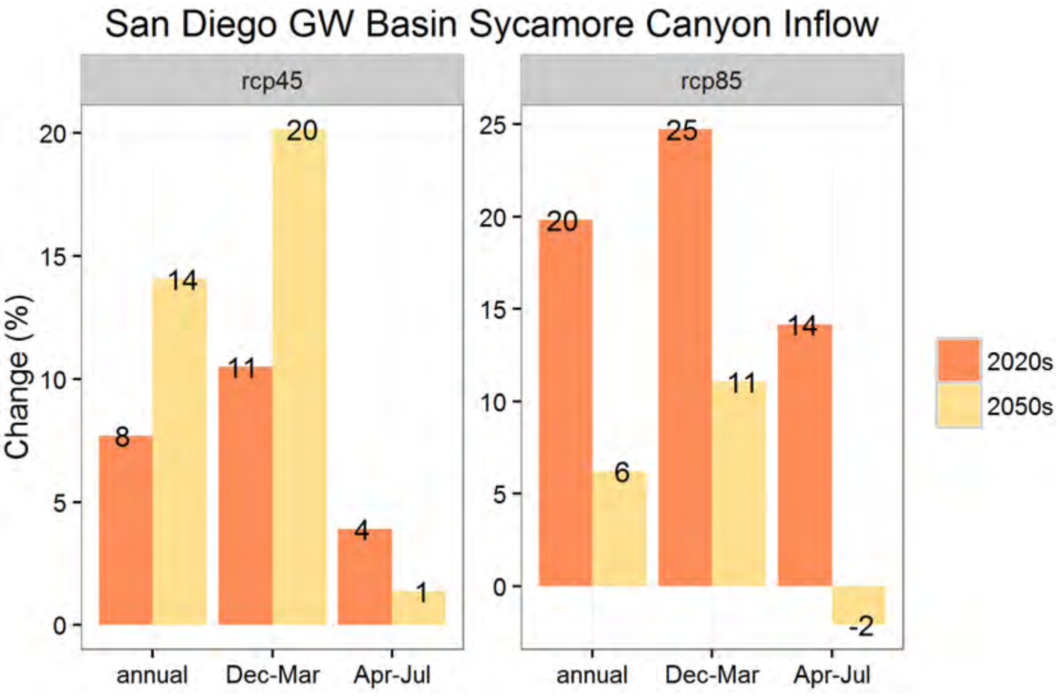

Figure 14.—San Diego River Groundwater Basin Sycamore Canyon streamflow recharge.

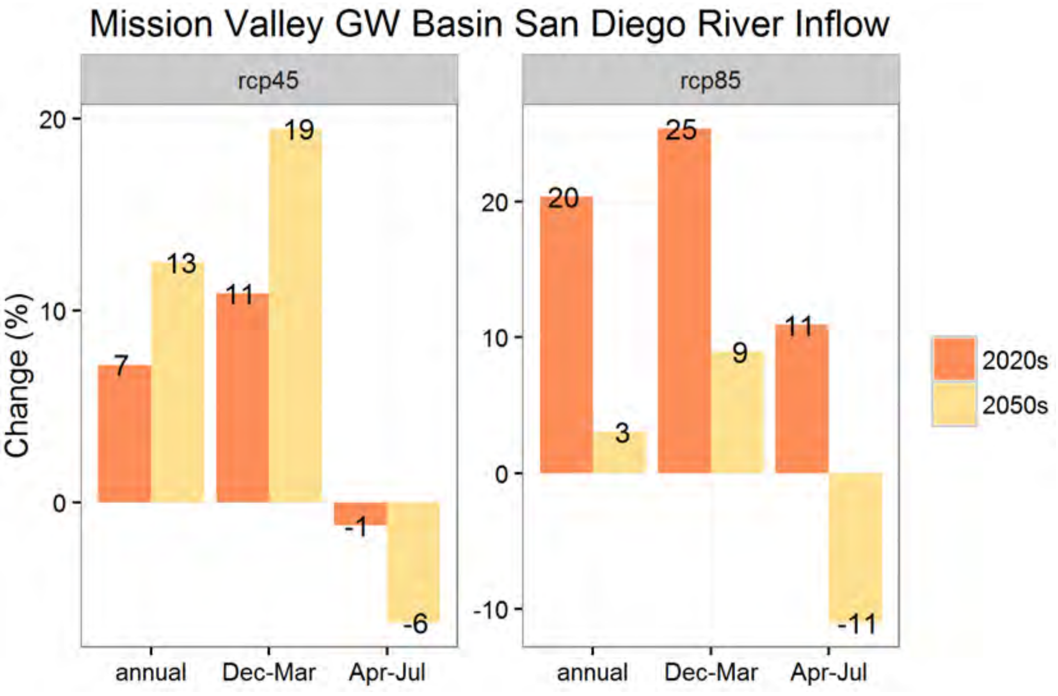

Figure 15.—Mission Valley Groundwater Basin San Diego River streamflow recharge.

# 4. Assessment of Imported Water Supply

San Diego County receives imported water from two primary sources: the Colorado River and the State Water Project. Results from the CRB Water Supply and Demand Study and the SSJ Basin Study were used to evaluate the climate change impacts on these two sources.

## 4.1 Colorado River

As discussed in Section 2.3, four measures were selected to evaluate historical and projected imported water supply to the Basin Study region, namely:

- Lower Basin shortage volume of 1.5 MAF in 5 years
- Lower Basin shortage volume of 1.0 MAF in 2 years
- Lake Mead elevation threshold (1000 ft elevation, or 4.5 MAF storage volume)
- Mean annual shortages to Lower Basin States

Table 7 shows the median Lake Mead volume shortage measures across climate change scenarios for all demand projections and operations strategies, updated for the future time periods evaluated in this study. Figures illustrating results in Table 7 are provided in figure 16 through figure 18. The percentage of traces exceeding 1 MAF at least once in any two year window or 1.5 MAF at least once in any five year window are shown. Percentage of traces exceeding 1 MAF in the 2020s under the Interim Operating Guidelines, and for all demand scenarios, range between 25.3% and 29%. Under the no action alternative, the percentage of traces increases to between 29.3% and 32.1%. By the 2050s the percentage of traces under the Interim Operating Guidelines will range from 53.2% under demand scenario D1 to 60.3% under demand scenario C1. Under the no-action alternative, shortages range from 72.6% under demand scenario B to 81.4% under scenario D2.

The percentage of traces with a shortage exceeding 1.5 MAF in any given five year window ranges from 33.5% to 34.6% under the Interim Operating Guidelines. Under the no-action alternative this increases to between 34.4% and 37.2%. The 2050s see a greater distinction between demand scenarios and operation strategies, with higher percent of traces exceeding the shortage under the no-action alternative. 61.7% to 68% of traces exceed 1.5 MAF under the interim guidelines and 73.5% to 82.7% of traces under the no-action alternative. Mean Lower Basin shortages are comparable in the 2020s across demand scenarios and management alternatives, from 0.22 to 0.229 MAF under the interim guidelines and from 0.31 to 0.34 MAF under the no-action alternative. There is a much larger difference between management alternatives by the 2050s, with the interim guidelines ranging between 0.38 and 0.43 MAF and the no-action alternative 0.84 and 1.0 MAF.

Table 7.—Summary of Lake Mead Shortage Measures

| Operations Scenario | Demand Scenario | Period | 1.0 MAF in 2 Years (%) | 1.5 MAF in 5 Years (%) | Shortage Volume (MAF) |
|---|---|---|---|---|---|
| IG | Scenario A | 2020s | 26.21 | 33.92 | 0.22 |
| NA | Scenario A | 2020s | 30.47 | 35.21 | 0.32 |
| IG | Scenario B | 2020s | 25.32 | 33.52 | 0.21 |
| NA | Scenario B | 2020s | 29.26 | 34.65 | 0.33 |
| IG | Scenario C1 | 2020s | 26.85 | 34.65 | 0.23 |
| NA | Scenario C1 | 2020s | 32.15 | 37.22 | 0.34 |
| IG | Scenario C2 | 2020s | 27.25 | 34.57 | 0.23 |
| NA | Scenario C2 | 2020s | 30.55 | 34.41 | 0.31 |
| IG | Scenario D1 | 2020s | 26.45 | 34.57 | 0.22 |
| NA | Scenario D1 | 2020s | 29.34 | 34.81 | 0.31 |
| IG | Scenario D2 | 2020s | 27.09 | 33.92 | 0.22 |
| NA | Scenario D2 | 2020s | 31.91 | 36.82 | 0.34 |
| IG | Scenario A | 2050s | 56.43 | 64.23 | 0.40 |
| NA | Scenario A | 2050s | 77.97 | 78.94 | 0.91 |
| IG | Scenario B | 2050s | 54.18 | 63.75 | 0.39 |
| NA | Scenario B | 2050s | 72.67 | 74.52 | 0.94 |
| IG | Scenario C1 | 2050s | 60.29 | 68.01 | 0.43 |
| NA | Scenario C1 | 2050s | 83.12 | 84.00 | 1.00 |
| IG | Scenario C2 | 2050s | 57.40 | 65.03 | 0.41 |
| NA | Scenario C2 | 2050s | 80.87 | 81.99 | 0.91 |
| IG | Scenario D1 | 2050s | 53.22 | 61.66 | 0.38 |
| NA | Scenario D1 | 2050s | 73.15 | 73.47 | 0.82 |
| IG | Scenario D2 | 2050s | 58.92 | 65.84 | 0.42 |
| NA | Scenario D2 | 2050s | 81.43 | 82.72 | 0.96 |

*Notes:* IG - Interim Operating Guidelines; NA – No Action; Demand scenarios are described in Section 2.3.1.

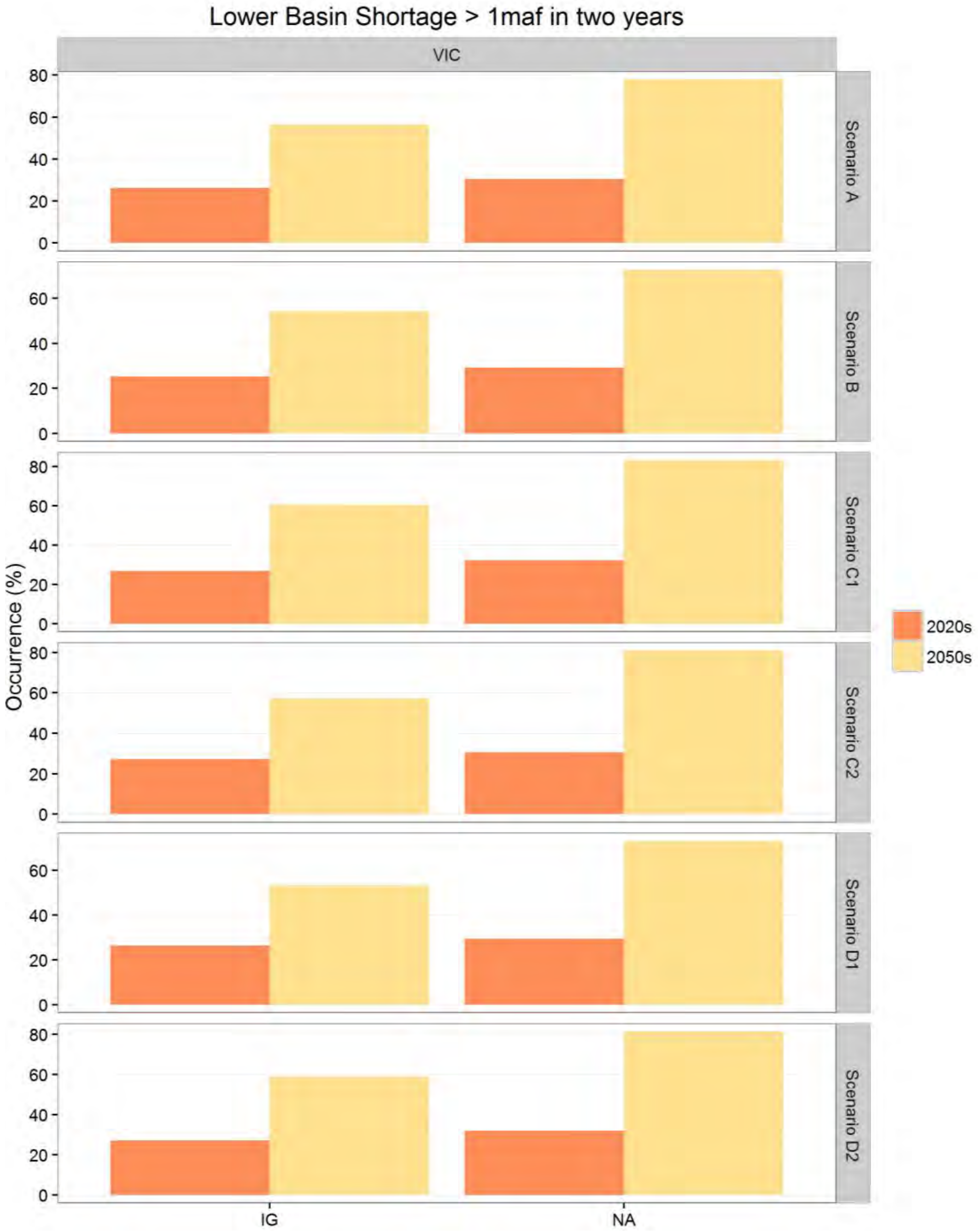

Figure 16.—Lower basin shortages > 1MAF in three years.

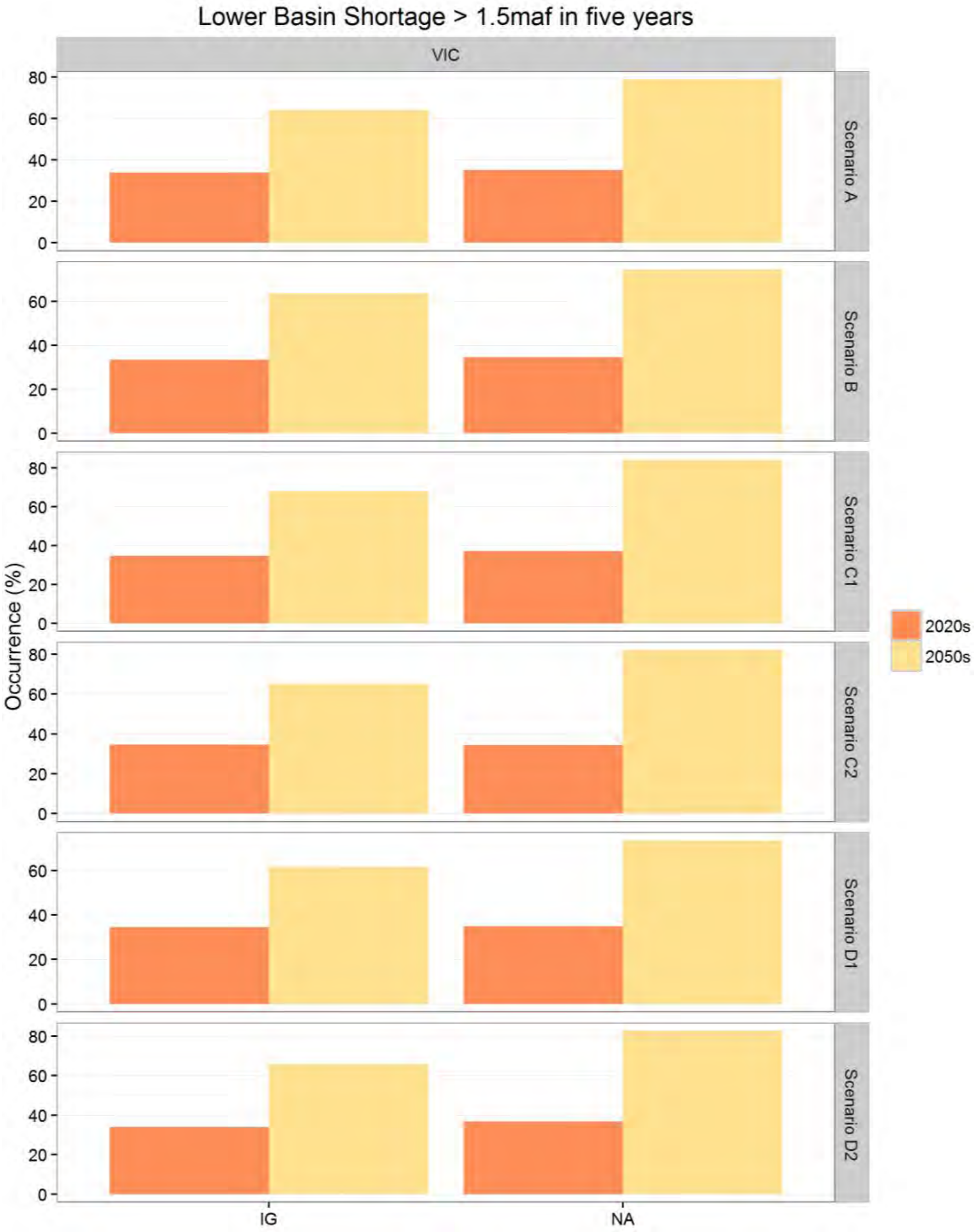

Figure 17.—Lower basin shortages > 1.5MAF in five years.

Figure 18.—Mean lower basin shortage.

Table 8 shows the frequency of Lake Mead levels falling below 1,000 ft. Median values across climate change scenarios are presented. For the 2020s, the percent of traces with Lake Mead levels below 1,000ft are comparable across demand scenarios and operations alternatives, ranging from 23.4% to 25.7% under the Interim Operating Guidelines and from 22.3% to 25.6% under the no-action alternative. By the 2050s, percent of traces with reservoir levels below 1,000ft under the Interim Operating Guidelines are higher than the no-action alternative, ranging from 49.3% to 55.6% as compared to 32.1% to 42.6%. Median values of projected change that are reported in table 8 are also illustrated in figure 19.

Table 8.—Summary of Lake Mead Level Threshold Exceedance

| Operations Scenario | Demand Scenario | Period | Exceedence of Lake Mead 1,000ft Threshold (%) |
|---|---|---|---|
| IG | Scenario A | 2020s | 25.21 |
| NA | Scenario A | 2020s | 25.37 |
| IG | Scenario B | 2020s | 23.81 |
| NA | Scenario B | 2020s | 22.32 |
| IG | Scenario C1 | 2020s | 24.74 |
| NA | Scenario C1 | 2020s | 23.67 |
| IG | Scenario C2 | 2020s | 25.72 |
| NA | Scenario C2 | 2020s | 23.65 |
| IG | Scenario D1 | 2020s | 23.37 |
| NA | Scenario D1 | 2020s | 23.50 |
| IG | Scenario D2 | 2020s | 25.05 |
| NA | Scenario D2 | 2020s | 24.94 |
| IG | Scenario A | 2050s | 53.55 |
| NA | Scenario A | 2050s | 38.09 |
| IG | Scenario B | 2050s | 51.45 |
| NA | Scenario B | 2050s | 32.09 |
| IG | Scenario C1 | 2050s | 55.56 |
| NA | Scenario C1 | 2050s | 41.11 |
| IG | Scenario C2 | 2050s | 54.26 |
| NA | Scenario C2 | 2050s | 42.56 |
| IG | Scenario D1 | 2050s | 49.33 |
| NA | Scenario D1 | 2050s | 40.26 |
| IG | Scenario D2 | 2050s | 56.27 |
| NA | Scenario D2 | 2050s | 41.15 |

*Notes:* IG - Interim Operating Guidelines; NA – No Action; Demand scenarios are described in Section 2.3.1.

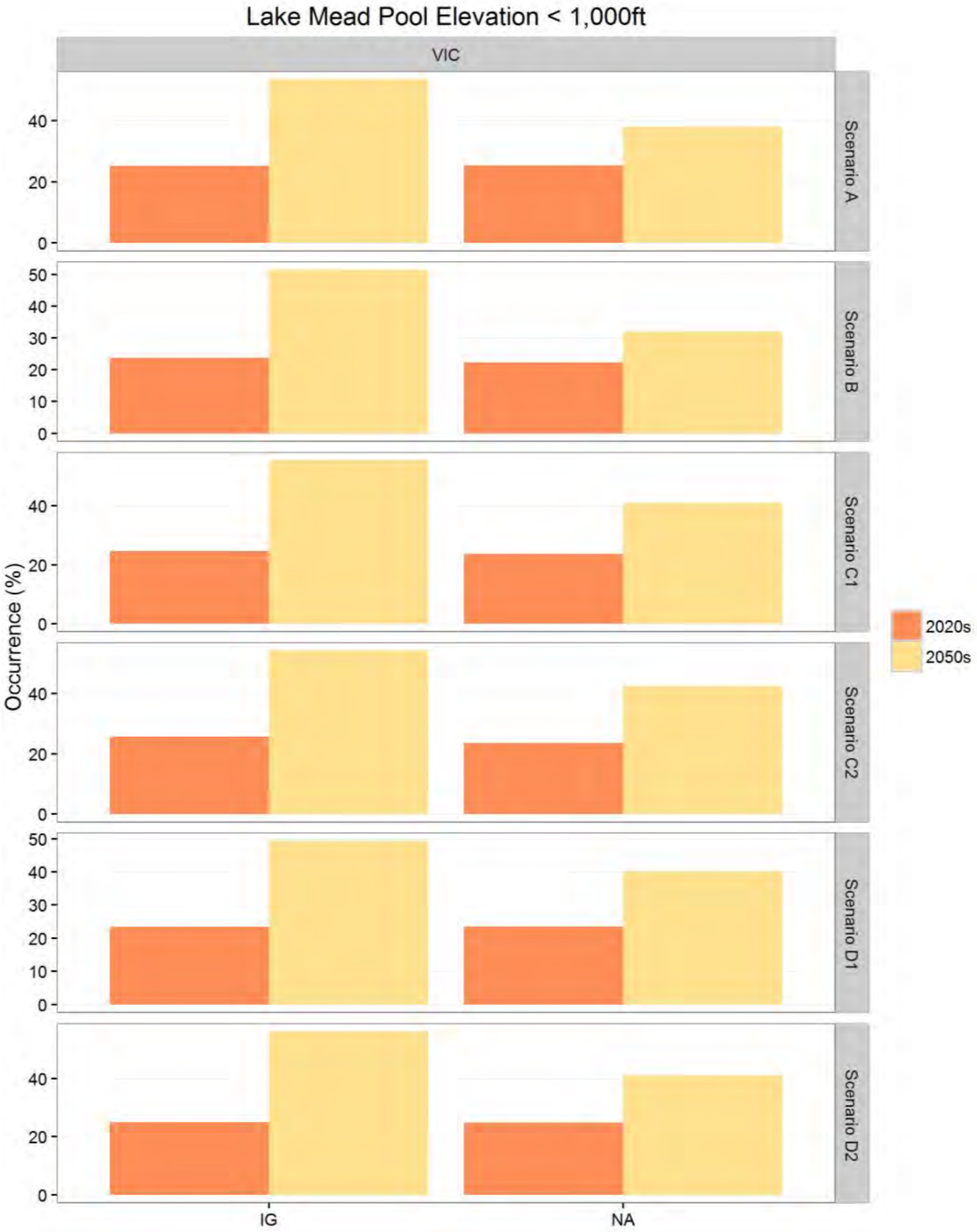

Figure 19.—Lake Mead pool elevations <1000ft.

## 4.2 State Water Project

The SSJ Basin Study used exports from the Banks pumping plant as a measure of evaluating climate change impacts on the State Water Project. Raw values were obtained from the SSJ Basin Study by socioeconomic and future climate scenario and then used to calculate exports for the two future periods used in this Basin Study. These computed exports are shown in Table 9.

Table 9.—Banks SWP Exports for Current Trend Socioeconomic Scenario

| Metric | Period | NoCC | Warm-Dry | Hot-Dry | Hot-Wet | Warm-Wet | Middle |
|---|---|---|---|---|---|---|---|
| Central Valley Project Exports – Banks Pumping Plant (TAF/year) | 2020s | 2,612 | 2,191 | 2,042 | 2,875 | 2,888 | 2,507 |
| | 2050s | 3,099 | 2,719 | 2,438 | 3,348 | 3,553 | 3,036 |

*Notes:* NoCC –No climate change scenario; TAF – thousand acre-feet.

The percent changes between the no climate change scenario and the current trend scenario are shown in Table 10. Under the median climate scenario, there are small decreases in exports. Much larger decreases in exports are seen for the Warm-Dry and Hot-Dry climate change scenarios, but the decreases remain fairly similar between the 2020s and 2050s. Moderate increases in exports are seen for both the Hot-Wet and Warm-Wet scenarios.

Table 10.—Banks SWP Exports % Change from No Climate Change for the Current Trend Socioeconomic Scenario

| Metric | Period | Warm-Dry | Hot-Dry | Hot-Wet | Warm-Wet | Middle |
|---|---|---|---|---|---|---|
| Central Valley Project Exports – Banks Pumping Plant Percent Change from No Climate Change | 2020s | -19% | -28% | 9% | 10% | -4% |
| | 2050s | -14% | -27% | 7% | 13% | -2% |

# 5. Assessment of Reservoir Inflows for Long Term Planning Model

Using a modified ensemble informed delta method approach described in Section 2.4, projected inflows to the study area's major reservoirs were developed to inform decision making using the CWASim long term planning model. As an example of estimated projected changes in reservoir inflow, monthly projected changes in streamflow at the San Vicente Dam location are shown in Figure 20. Projected changes in streamflow are more pronounced in January through May, as compared to the rest of the year, and there is a broader range of changes between the scenarios in these months. Changes in precipitation appear to have a greater influence on streamflow than do changes in temperature, with both the warm-wet and hot-wet scenarios showing greater increases in streamflow than the middle scenario.

Monthly change factors were calculated for each of the ten reservoir inflows required by the long-term planning model, CWASim: Loveland, Barrett, El Capitan, Hodges, Morena, Lower Otay, San Vicente, Sutherland, Sweetwater, and Wohlford. Future basin study tasks will use this planning model to evaluate system performance under the five future climate scenarios and two future periods. The model will be used to examine alternative water supply infrastructure and operations to meet future water supply demands in San Diego County. Appendix B provides a comparison of monthly average inflows between the VIC simulations and CWASim inflows for each reservoir.

Projected changes in mean annual streamflow at San Vicente Dam using the ensemble informed delta approach are shown in Table 11. Table 12 summarizes projected change in streamflow at the same location using the results from the transient analysis (refer to Section 3.2). The transient analysis used RCP4.5 (moderate warming) and RCP8.5 (more severe warming) as discussed in Section 2.1. These two scenarios (RCP4.5 and RCP8.5) are not directly comparable to the five developed scenarios using the ensemble informed delta method approach; however, projected streamflow changes under both RCP4.5 and RCP8.5 fall within the range of the five ensemble informed delta scenarios for both future periods.

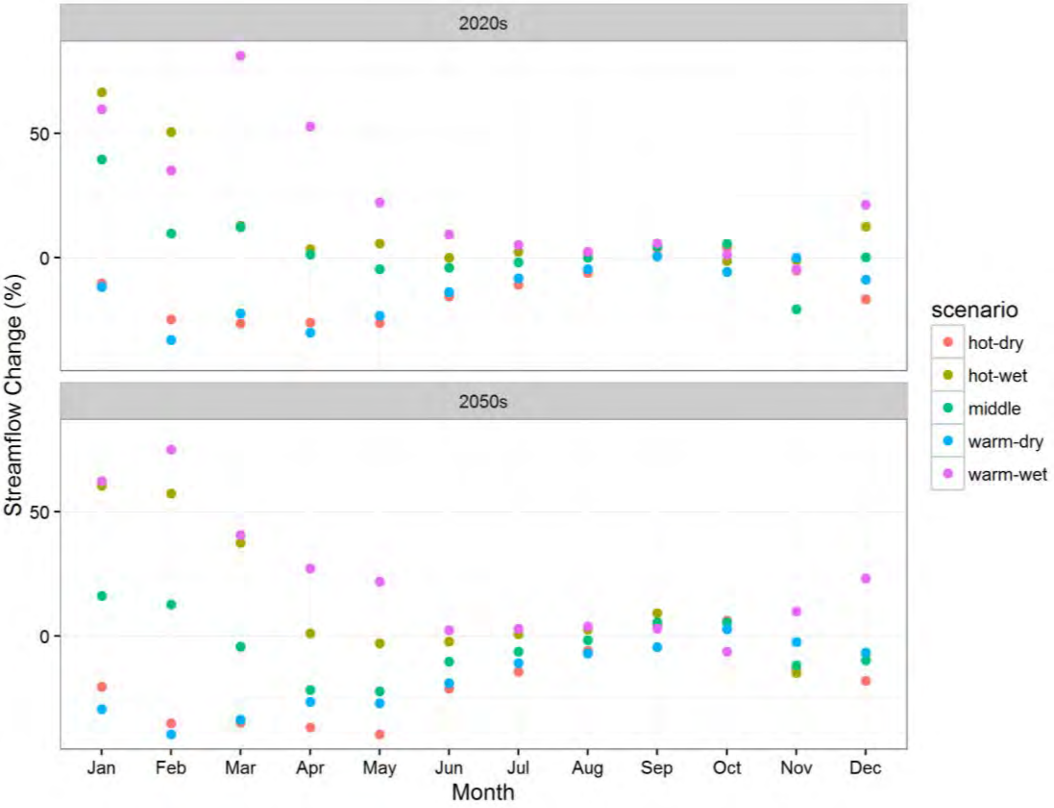

Figure 20.—San Vicente Reservoir ensemble informed delta monthly streamflow changes.

Table 11.—San Vicente Reservoir Ensemble Informed Delta Annual Streamflow Changes

| Reservoir Inflow | Period | Scenario | VIC Annual Change (%) |
|---|---|---|---|
| San Vicente | 2020s | cool-dry | -21% |
| San Vicente | 2020s | cool-wet | 46% |
| San Vicente | 2020s | hot-dry | -20% |
| San Vicente | 2020s | hot-wet | 25% |
| San Vicente | 2020s | middle | 11% |
| San Vicente | 2050s | cool-dry | -28% |
| San Vicente | 2050s | cool-wet | 42% |
| San Vicente | 2050s | hot-dry | -28% |
| San Vicente | 2050s | hot-wet | 30% |
| San Vicente | 2050s | middle | -1% |

Table 12.—San Vicente Reservoir Transient Analysis Annual Streamflow Changes

| Reservoir Inflow | Period | Scenario | VIC Annual Change (%) |
|---|---|---|---|
| San Vicente | 2020s | rcp45 | 9% |
| San Vicente | 2020s | rcp85 | 22% |
| San Vicente | 2050s | rcp45 | 15% |
| San Vicente | 2050s | rcp85 | 8% |

The ensemble informed delta scenarios and associated changes in reservoir inflows will be used in future study tasks to inform CWASim simulations. Tasks 2.3 and 2.4 of the Basin Study will examine water supply and demand under current and future climate through modeling of the San Diego region's water supply system. Monthly change factors, developed using the ensemble informed delta method, have been applied to historical inflows developed for the CWASim model to generate new inflows representing the five future climate scenarios and two future periods (refer to Section 2.4).

In addition, a spreadsheet calculator has been developed in conjunction with the planning model to estimate required outdoor water demands. This spreadsheet calculator uses precipitation and temperature to estimate outdoor water demands. Each water district is mapped to a representative VIC node location for the precipitation and temperature inputs. These inputs been obtained for the five ensemble informed delta future climate scenarios and more information can be found in Appendix C.

# 6. Uncertainties in the Analysis

This section summarizes uncertainties associated with various aspects of the analysis presented in this technical report to the San Diego Watershed Basin Study. The uncertainties discussed below include the development and use of climate change scenarios, as well as application of a surface hydrologic model to evaluate climate change impacts. Additional discussion regarding the use of GCM climate projections and applied downscaling techniques is provided by Reclamation (2011). The nature of the uncertainties described in Reclamation (2011) is only briefly described below.

## 6.1 Global Climate Projections, Modeling, and Downscaling

There are many types of uncertainty associated with the use and downscaling (in space and time) of GCM projections. This section identifies some of these uncertainties to provide context to the discussion of climate change impacts on local and imported water supplies in the Basin Study region.

The climate projections considered in this report represent a range of future GHG emission pathways (Reclamation 2011); however, uncertainties associated with estimating these pathways, including those introduced by assumptions of global growth and land use, are not explored in this analysis. The analyses discussed in this report rely on both CMIP3 and CMIP5 based simulations, which incorporate various estimates of future GHG emissions. Figure 4 illustrates similarities and differences among these estimated pathways.

GCMs themselves have associated uncertainty with respect to their initial conditions and representation of physical processes. Model simulations may have substantial differences in their simulated long timescale climate patterns. Regarding representation of physical processes, the most recent generation of GCM simulations (based on CMIP5) incorporate, in many cases, improved understanding of the climate system. In addition, there may be biases in GCM simulations that affect apparent climate change expressed by the simulations. Current science suggests that GCM projections, and derived climate change scenarios from these projections, are equally likely. Thus it is advantageous to consider the range of projected climate change from these available simulations.

This Basin Study analysis used a combination of transient (i.e. evolving through time) GCM projections and period change climate scenarios (i.e. perturbed historical climate incorporating projected climate change for select future time periods). There is uncertainty associated with use of different approaches for characterizing future climate. The intent is to explore the range of projected climate change according to available GCM projections. Where possible, this report identifies different approaches used in analysis and compares results between them (e.g. tables 14 and 15 in Chapter 5).

As part of the Basin Study, future scenarios of reservoir inflow were developed for the CWASim long term planning model. The approach for developing future scenarios involved a period change approach whereby perturbed historical streamflow scenarios were generated for select locations based on ensembles of selected GCM projections of temperature and precipitation. This approach is described in detail in Section 2.4. Because projected mean change was applied to historical reservoir inflows by month, there may be internal inconsistency in daily flows at the month transitions (e.g. going from May 31 to June 1). Testing was conducted to ensure these effects on the data are minimal. However, there is uncertainty associated with this approach.

One additional uncertainty associated with the methodology used to characterize climate change impacts is the use of 10 year windows of time (as opposed to longer periods) for computing change between future and historical conditions (refer to table 5). Typically a longer time window is used to compute change between a future period and historical reference period because it is more likely to capture the climate change signal as opposed to shorter time scale natural variability, which occurs along with climate change. Hence, use of 10 year windows may be more likely to incorporate the effects of limited variability on climate.

## 6.2 Climate Projections from CMIP3 and CMIP5

This Basin Study analysis used a combination of CMIP5 and CMIP3 based projections. This report identifies the approach used for each type of analysis to provide context and clarity of methods. For example, range of CMIP5 based transient climate projections were used for analysis of projected changes in local water supplies at select locations. In contrast, a combination of CMIP3 and CMIP5 based period change climate change scenarios were used to evaluate projected changes in imported water supplies.

It is important to understand that models and scenarios of emissions used in CMIP5 differ in several ways from those used in CMIP3. First, model resolution has generally increased by a factor of 2 (i.e., CMIP5 models have, on average, twice the number of grid cells representing the atmosphere than CMIP3 models). Second, although many of the models used in CMIP5 are similar in structure to those used in CMIP3, many incorporate updated physics and added, or improved, individual process representation. Some of the models used in CMIP5 reflect a fundamental advancement in model structure by incorporating biogeochemical cycling; this new class of models is referred to as Earth System Models. Third, there are notable differences in precipitation for some regions (e.g., greater warming over the Upper Columbia Basin, less precipitation over the northern Great Plains, and more precipitation over California and the Upper Colorado Basin). Projections showing wetter portions of California and the Upper Colorado are notable because they challenge the prevailing perspective of climate change impacts to the region that has been held since 2007 (informed by CMIP3 projections): namely, that these regions will become drier, resulting in reduced runoff. It is important to recognize that while CMIP5 offers new information, more work is required to better understand CMIP5 and its differences compared to CMIP3. In some regions, model resolution is likely the leading factor in these differences. In the North American Monsoon region, for example, the higher resolution of CMIP5 models allows these models to better capture the landward moisture transport and overland convection that results in monsoon precipitation events. These processes were not resolved in the lower resolution CMIP3 models.

The CMIP5 projections represent a new opportunity to improve our understanding of climate science, which is evolving at a steady pace. While CMIP5 projections may inform future analyses, many completed and ongoing studies are informed by CMIP3 projections that were selected as the best information available at the time of the study. Two examples of studies using CMIP3 projections include the CRB Water Supply and Demand Study and the SSJ Basin Study. Even though CMIP5 provides the latest available suite of climate projections, it has not been determined to be a better or more reliable source of climate projections compared to existing CMIP3 projections. Current state of practice relies on one or both suites of climate projections for use in impacts studies.

## 6.3 Quality of Hydrologic Model Used to Assess Hydrologic Effects

In Reclamation (2011) and most of the cited literature sources, the chosen approach for assessing surface water hydrologic effects has typically involved using surface water hydrologic models, which may not represent key hydrologic processes related to groundwater and/or large water bodies. Some of these imperfections could be reduced through refined redevelopment, or calibration, of the model. Another approach for exploring the uncertainty associated with the VIC hydrologic model, which was not taken in this study, would be to apply additional surface water hydrology models and compare results across simulations.

In the case of this Basin Study, existing VIC model simulations were used and model calibration was not performed as part of the study, and is reflected in some of the simulated hydrographs (see Appendix B). Additional efforts may be invested in this area; however, focusing on a change of projected future conditions relative to historical conditions is a scientifically defensible approach taken in numerous climate change impacts studies, and is the approach taken in this Basin Study analysis.

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# Appendix A – Surface Water Figures

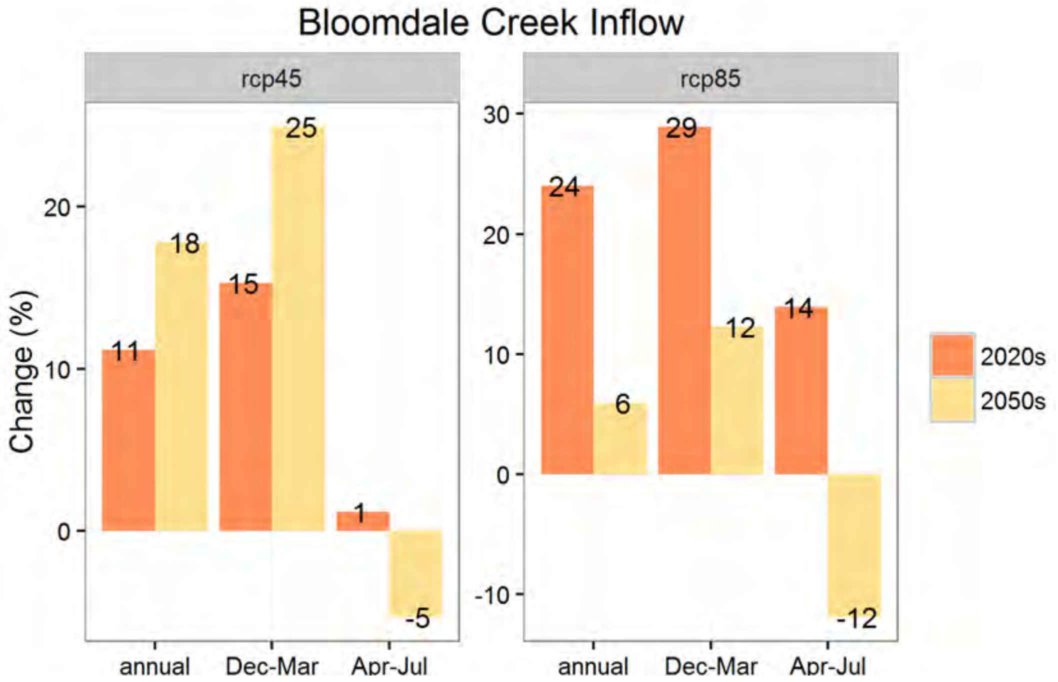

Figure A-1.—Projected change in mean annual and seasonal VIC simulated natural streamflow at Bloomdale Creek Inflow location.

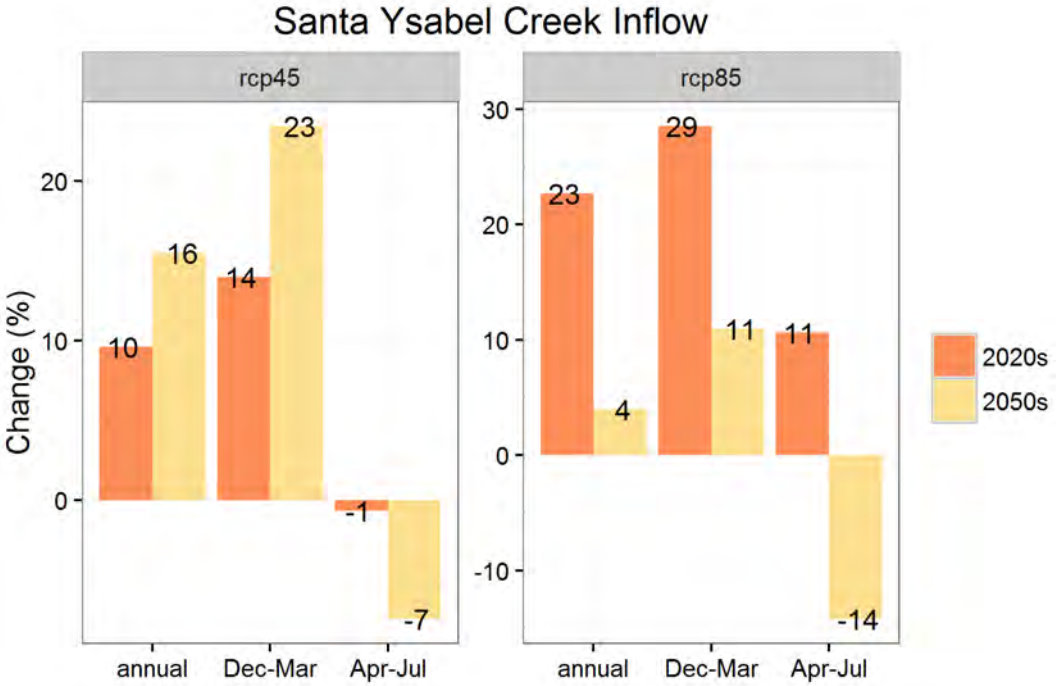

Figure A-2.—Projected change in mean annual and seasonal VIC simulated natural streamflow at Santa Ysabel Creek Inflow location.

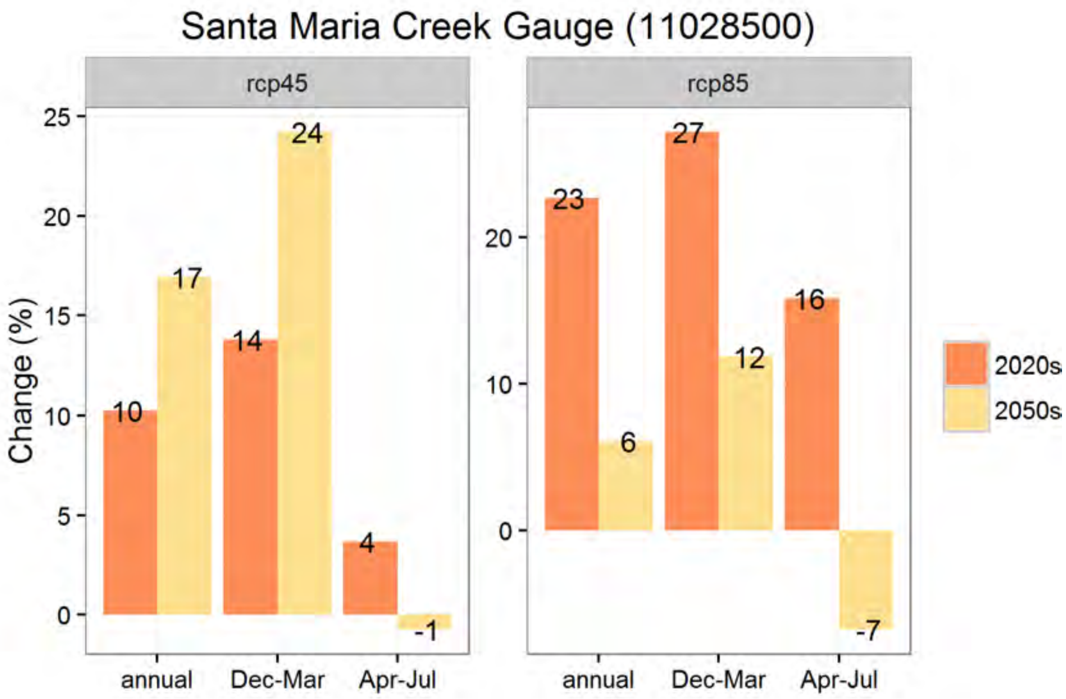

Figure A-3.—Projected change in mean annual and seasonal VIC simulated natural streamflow at Santa Maria Creek Inflow location.

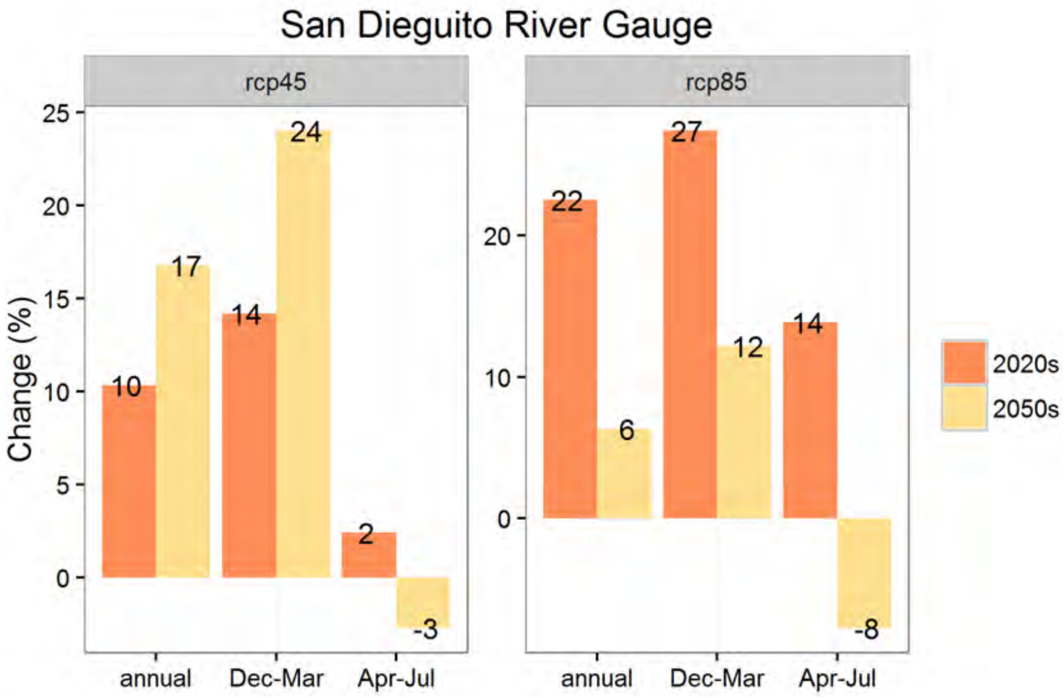

Figure A-4.—Projected change in mean annual and seasonal VIC simulated natural streamflow at San Dieguito Creek Inflow location.

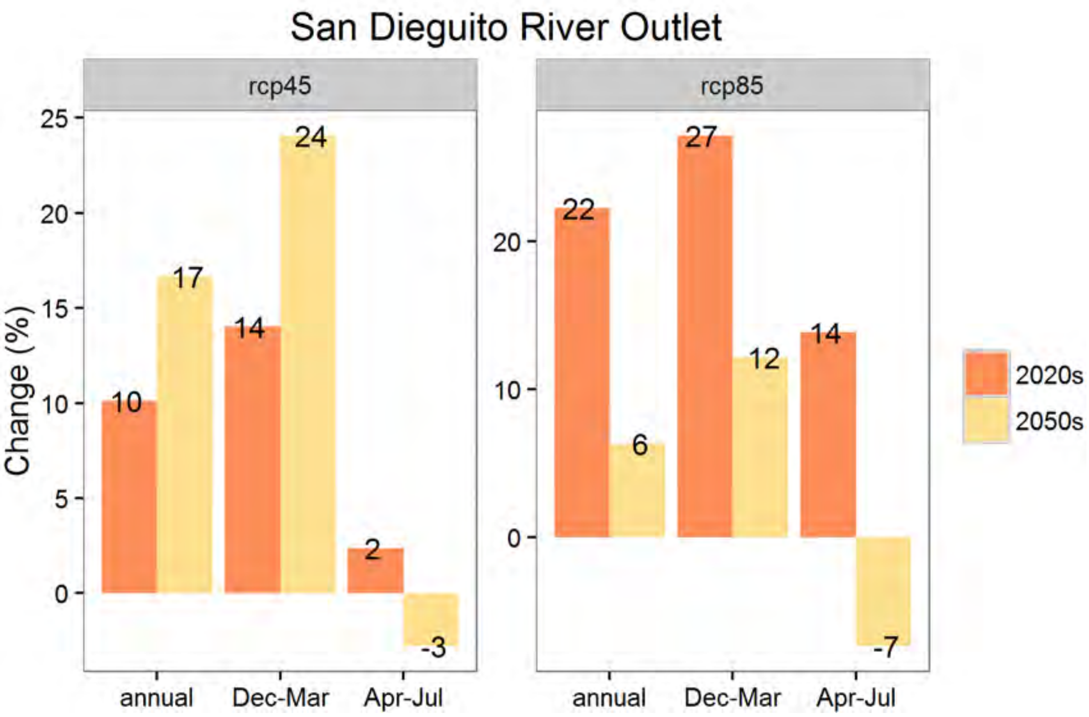

Figure A-5.—Projected change in mean annual and seasonal VIC simulated natural streamflow at San Dieguito River Outlet location.

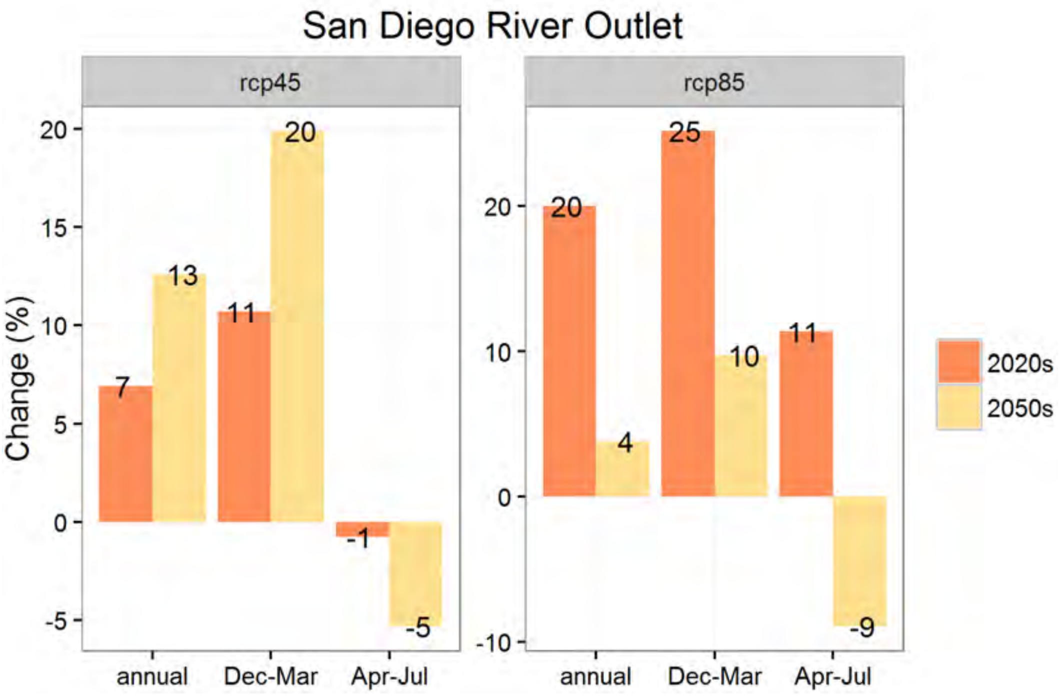

Figure A-6.—Projected change in mean annual and seasonal VIC simulated natural streamflow at San Diego River Outlet location.

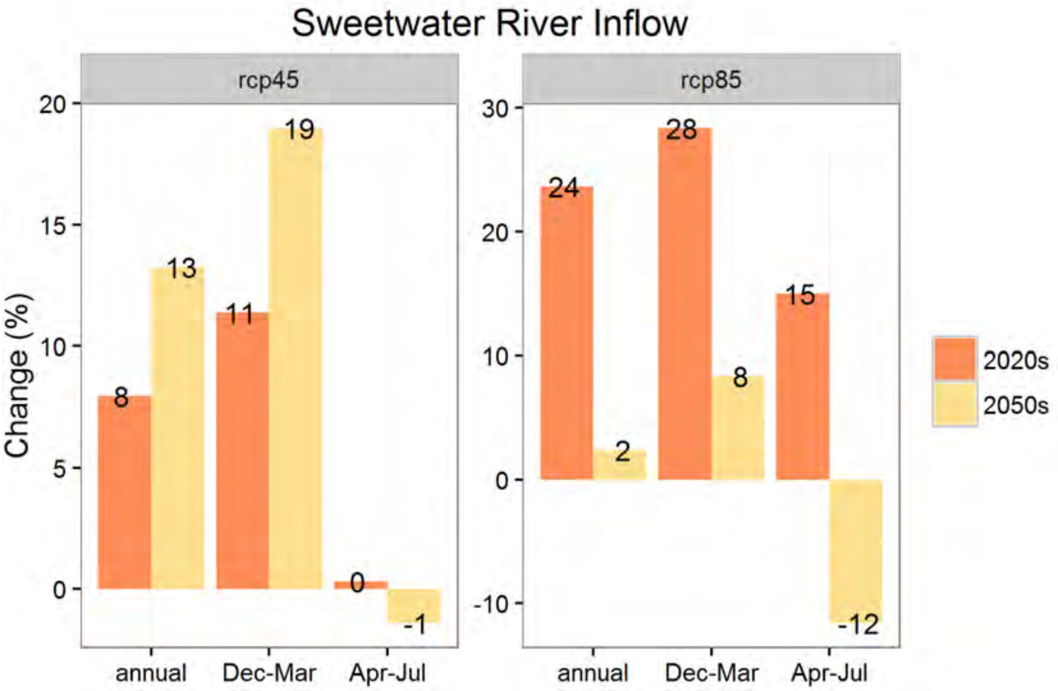

Figure A-7.—Projected change in mean annual and seasonal VIC simulated natural streamflow at Sweetwater River Inflow location.

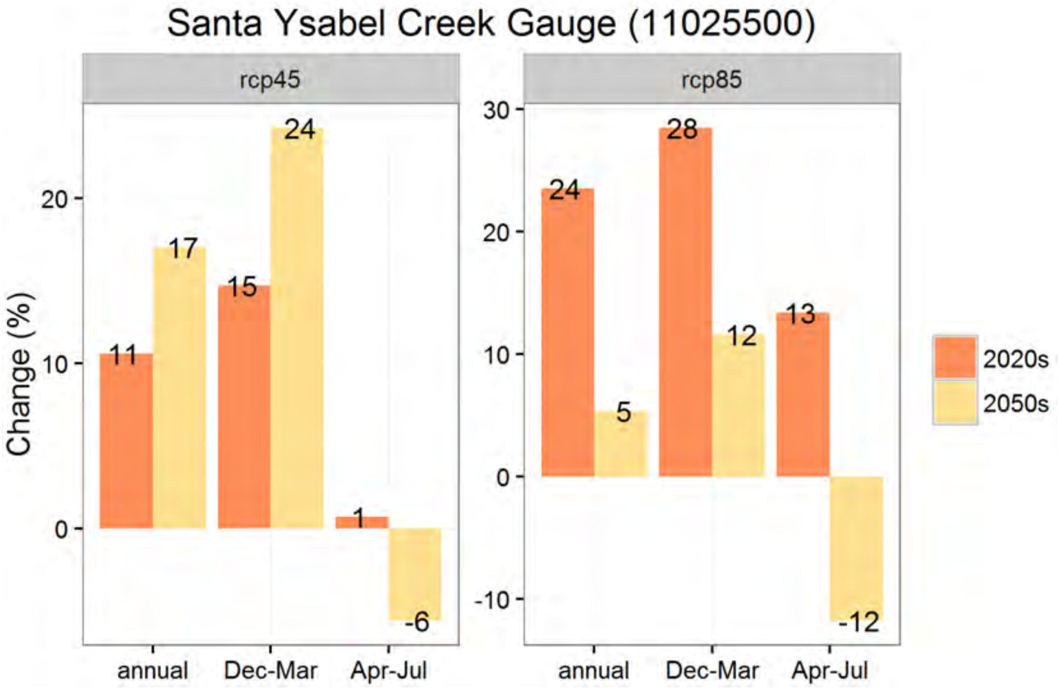

Figure A-8.—Projected change in mean annual and seasonal VIC simulated natural streamflow at Santa Ysabel Creek Gauge location.

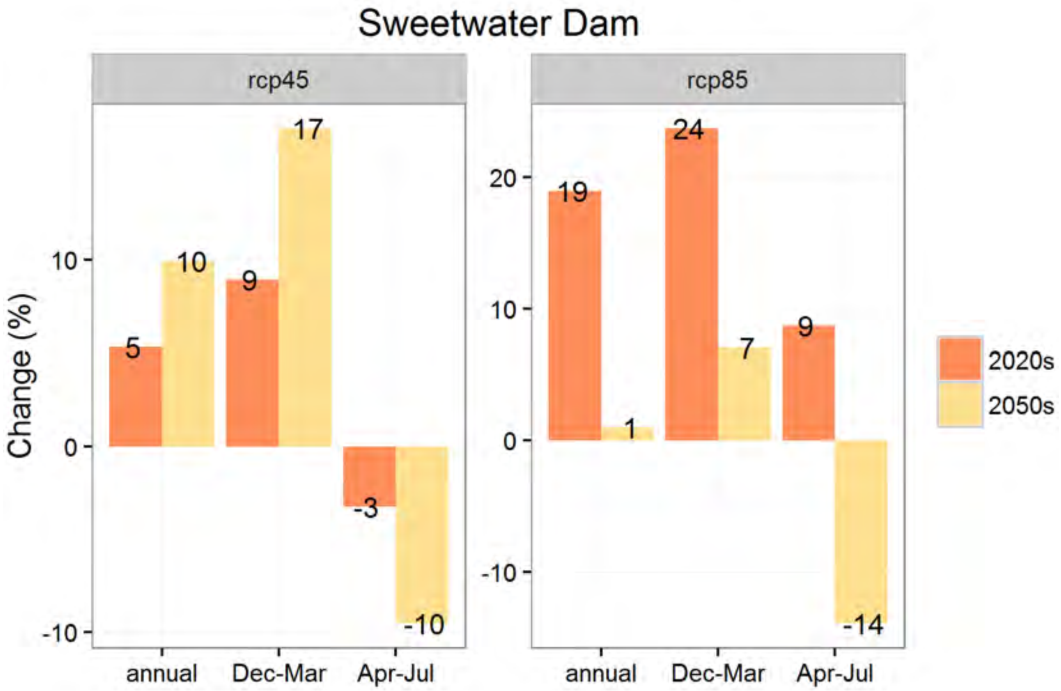

Figure A-9.—Projected change in mean annual and seasonal VIC simulated natural streamflow at Sweetwater Dam outflow location.

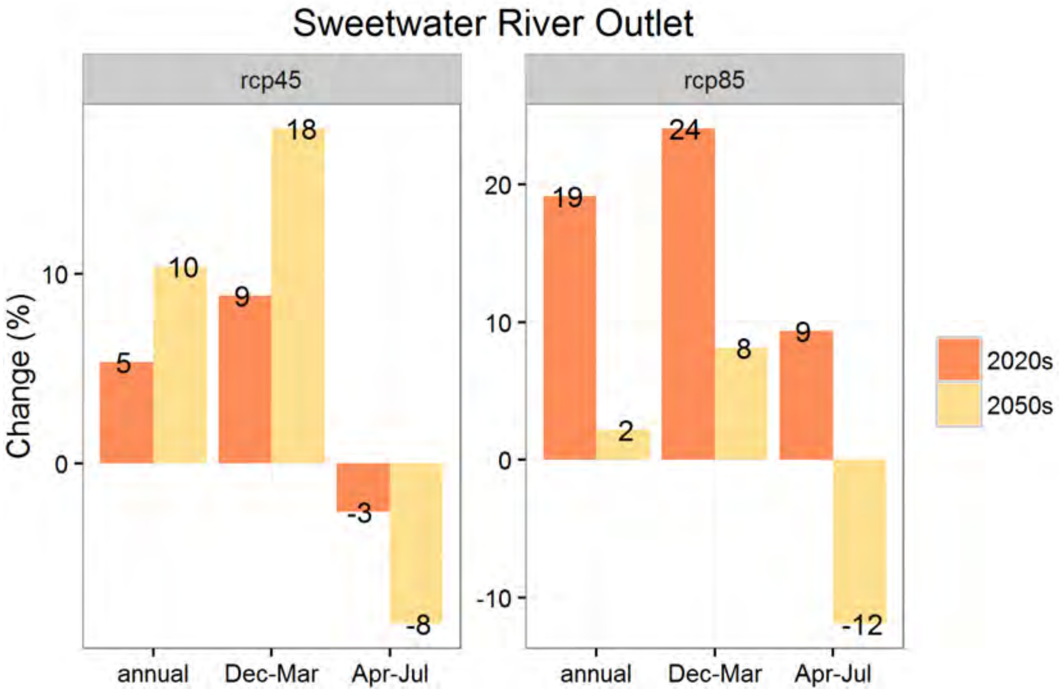

Figure A-10.—Projected change in mean annual and seasonal VIC simulated natural streamflow at Sweetwater River Outlet location.

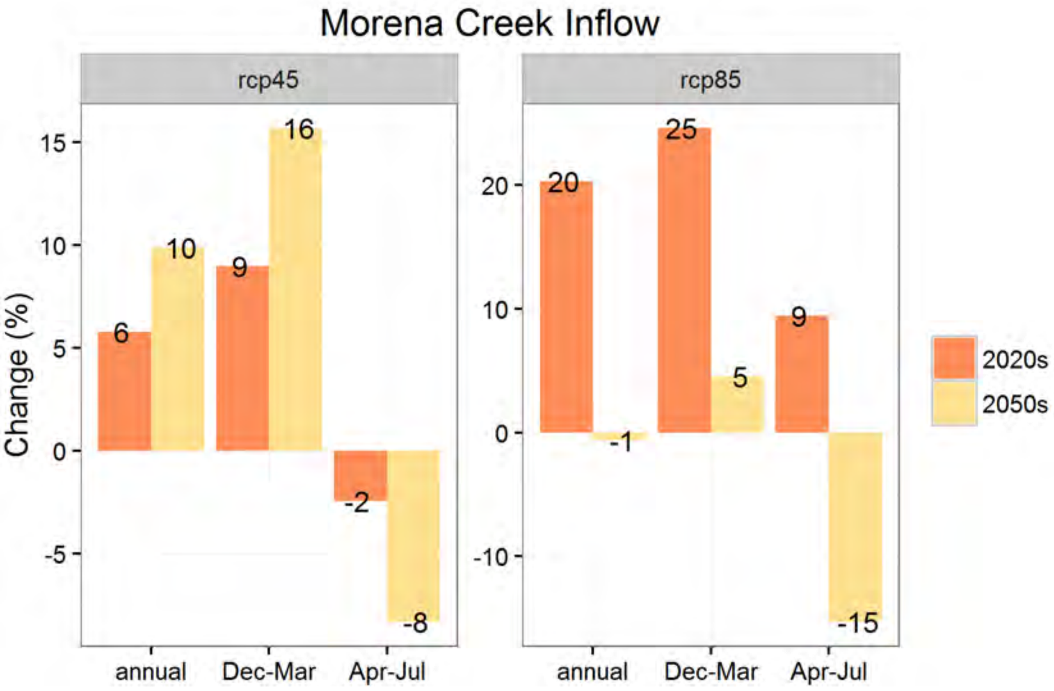

Figure A-11.—Projected change in mean annual and seasonal VIC simulated natural streamflow at Morena Creek Inflow location.

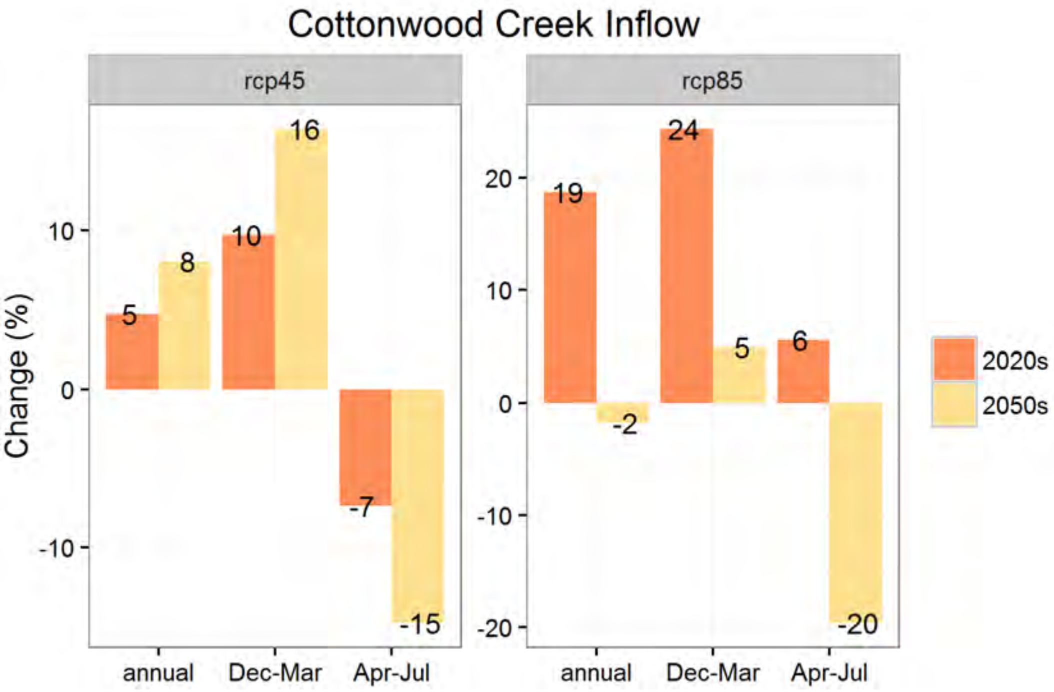

Figure A-12.—Projected change in mean annual and seasonal VIC simulated natural streamflow at Cottonwood Creek Inflow location.

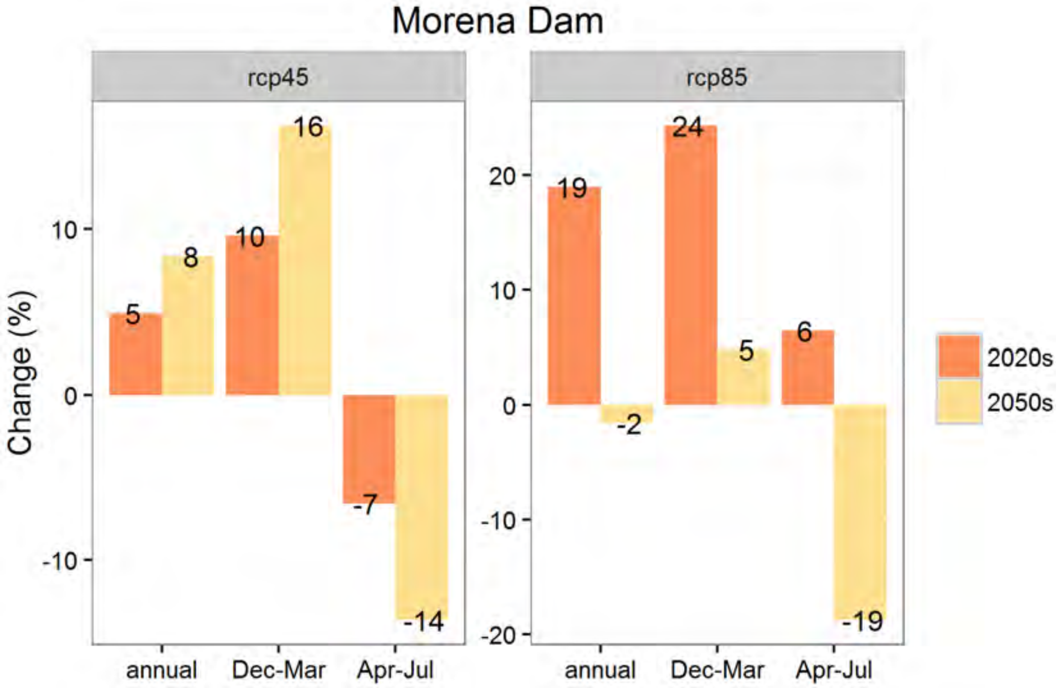

Figure A-13.—Projected change in mean annual and seasonal VIC simulated natural streamflow at Morena Dam outflow location.

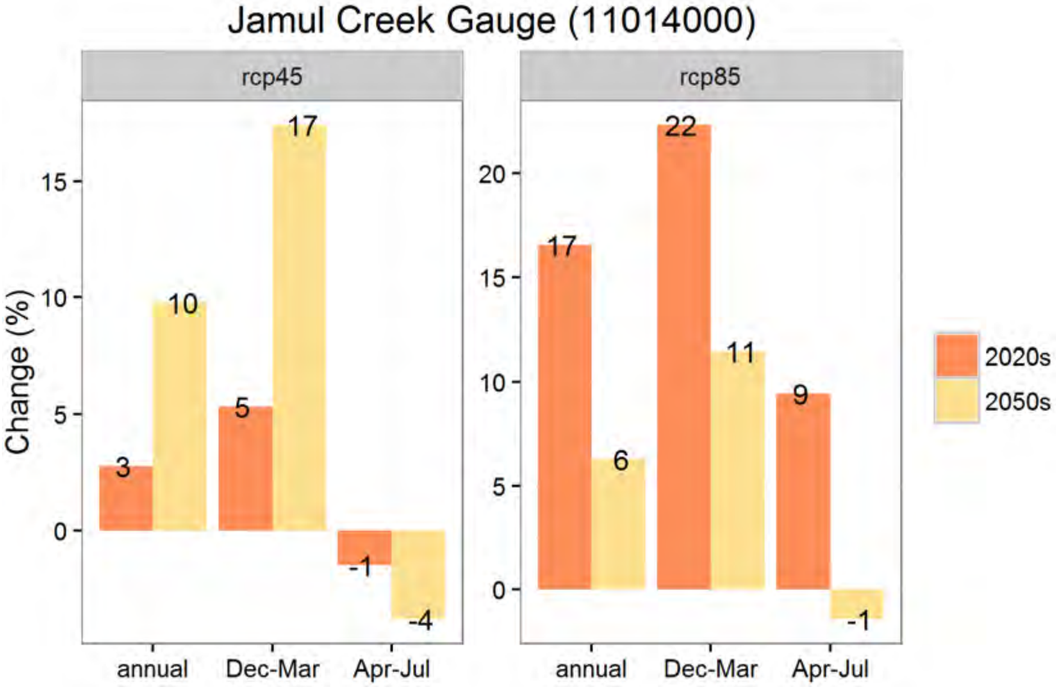

Figure A-14.—Projected change in mean annual and seasonal VIC simulated natural streamflow at Jamul Creek Gauge location.

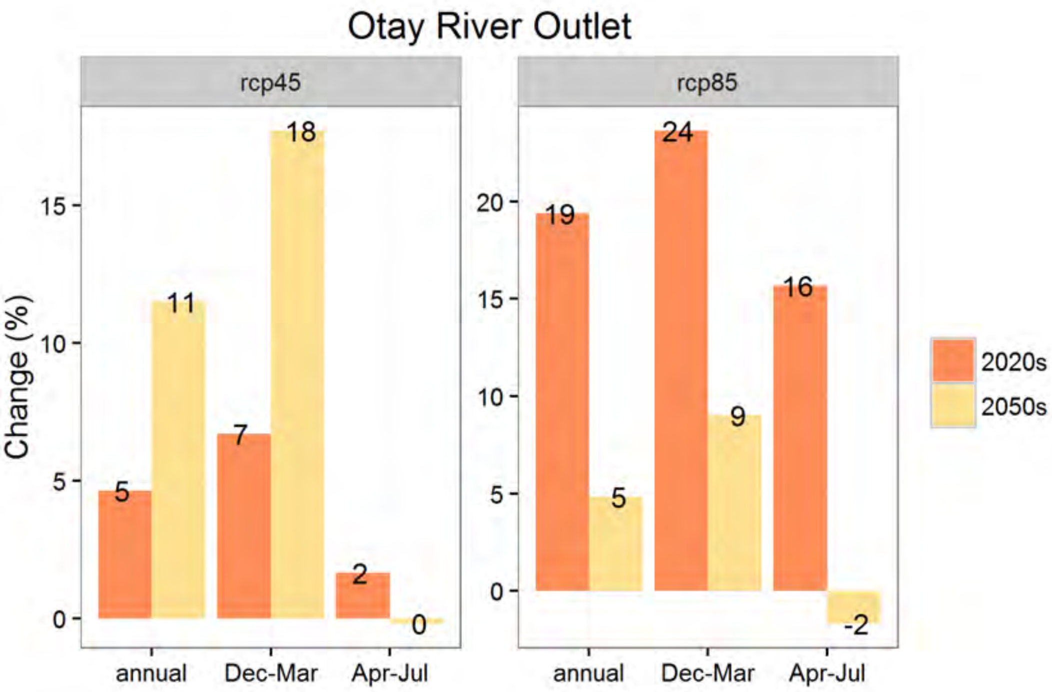

Figure A-15.—Projected change in mean annual and seasonal VIC simulated natural streamflow at Otay River Outlet location.

# Appendix B – VIC Inflow Comparison

The monthly mean values for reservoir inflows obtained from VIC naturalized flows were compared to reservoir inflows derived from a mass-balance approach for use in the CWASim planning model. Plots for each reservoir are shown below.

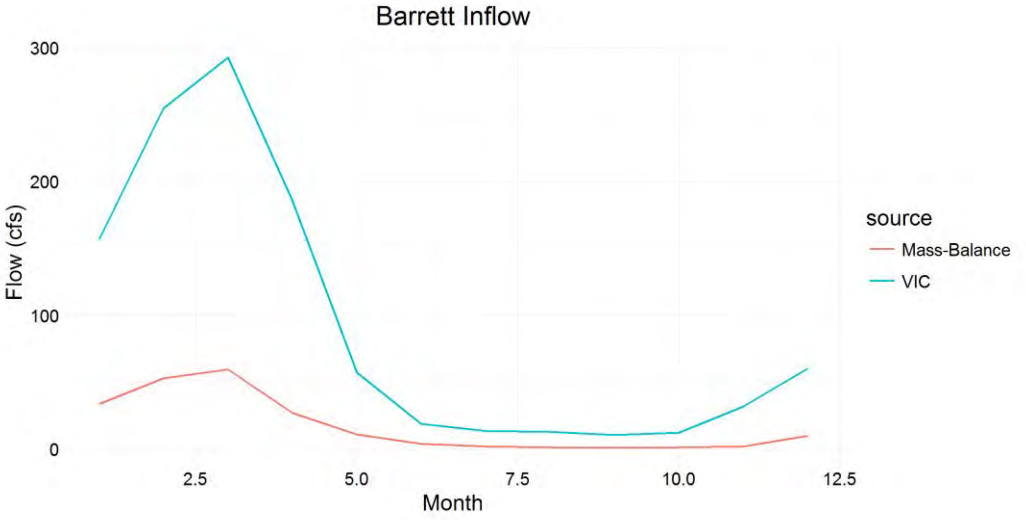

Figure B-1.—Comparison of mean monthly streamflow at Barrett Inflow location.

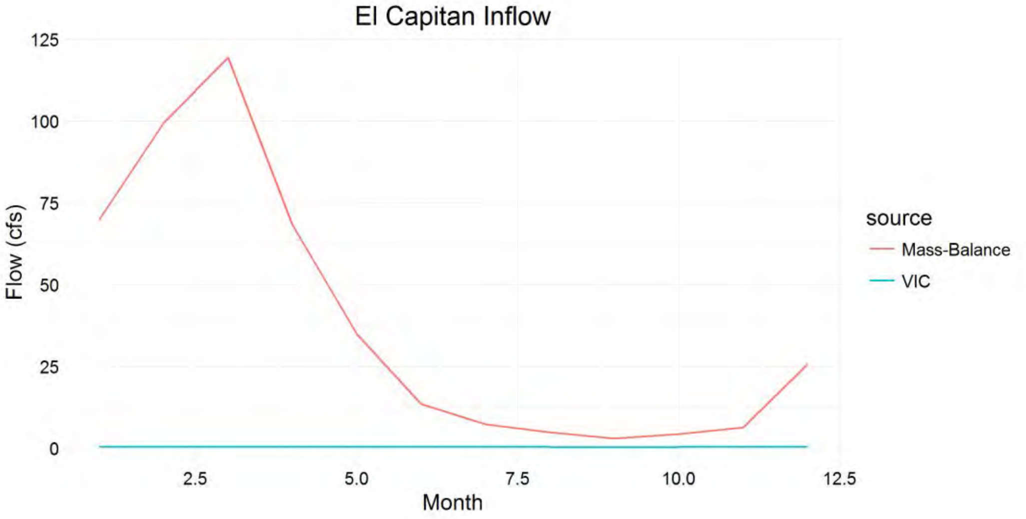

Figure B-2.—Comparison of mean monthly streamflow at El Capitan Inflow location.

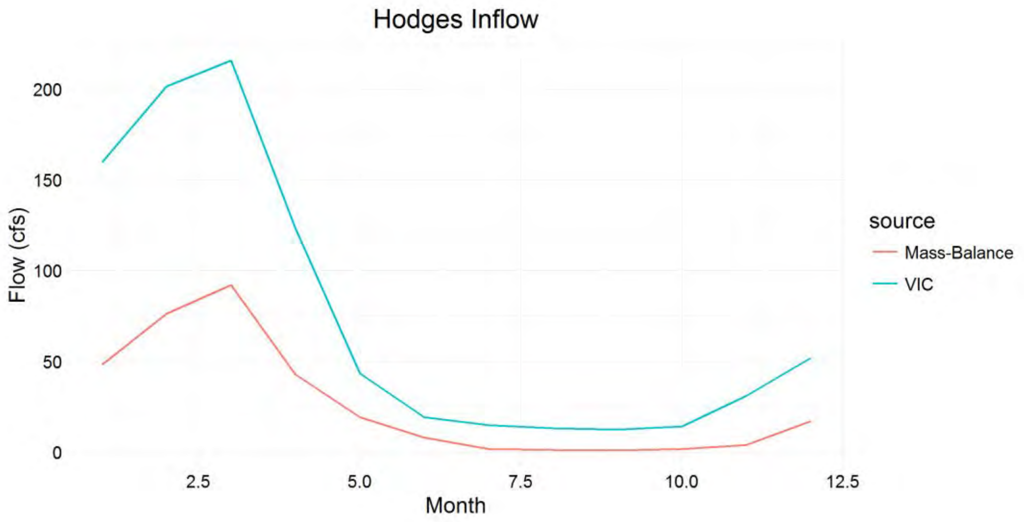

Figure B-3.—Comparison of mean monthly streamflow at Hodges Inflow location.

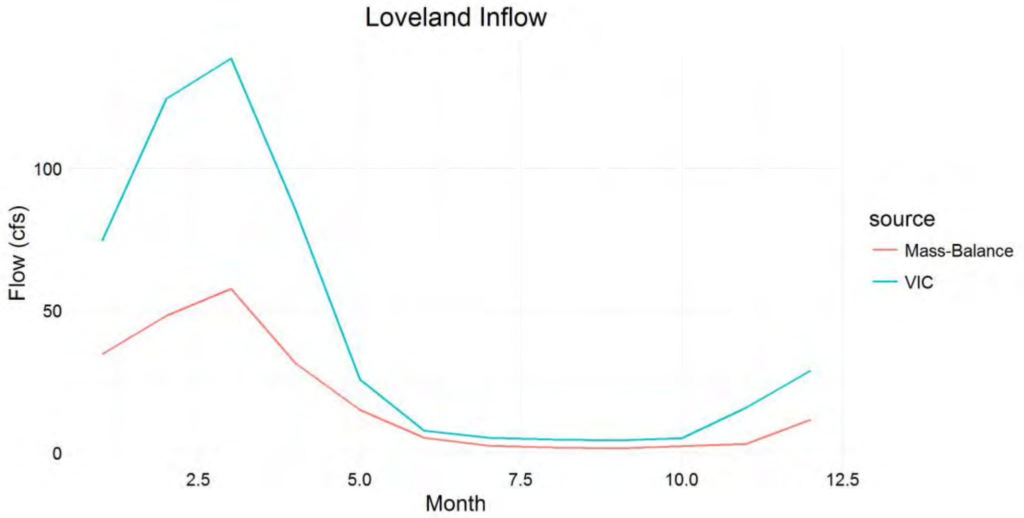

Figure B-4.—Comparison of mean monthly streamflow at Loveland Inflow location.

Figure B-5.—Comparison of mean monthly streamflow at Lower Otay Inflow location.

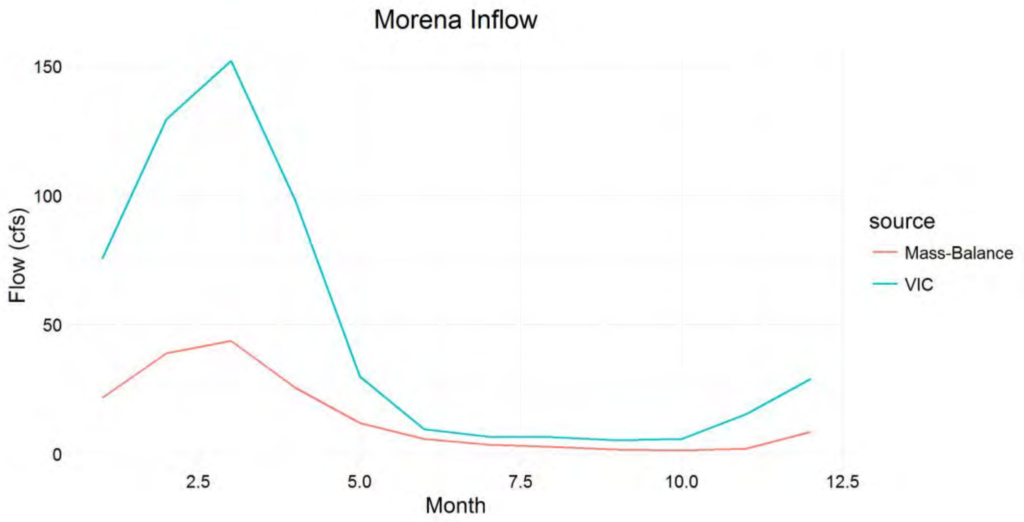

Figure B-6.—Comparison of mean monthly streamflow at Morena Inflow location.

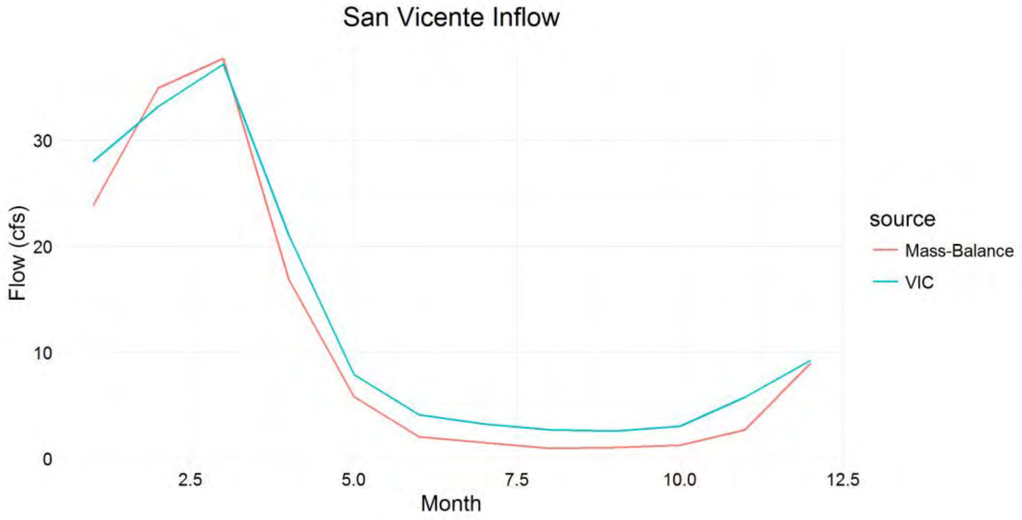

Figure B-7.—Comparison of mean monthly streamflow at San Vicente Inflow location.

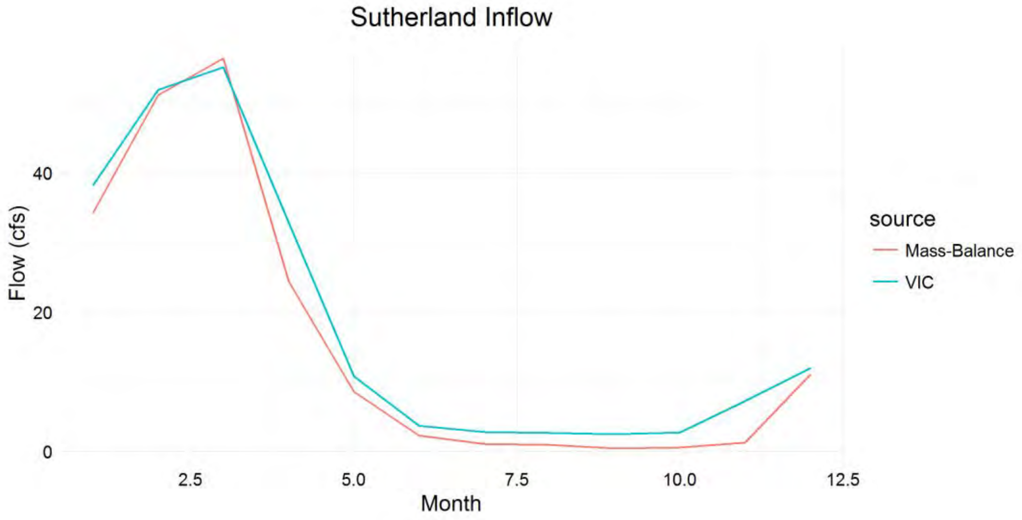

Figure B-8.—Comparison of mean monthly streamflow at Sutherland Inflow location.

# Appendix C – Precipitation and Temperature Inputs

CWASim, a Goldsim-based water system simulation model will be used to support future basin study tasks including evaluating system performance under different climate change scenarios, and alternative evaluation. The model requires outdoor water demands for water districts within San Diego County. A spreadsheet model has been developed that uses precipitation and temperature as inputs, and calculates PET-based water demands. For each water district in the model, a representative VIC grid node has been identified to obtain the precipitation and temperature inputs. These nodes are listed in table C-1.

Table C-1.—Water District Representative VIC Nodes

| Agency | Longitude | Latitude |
|---|---|---|
| Otay Water District (East) | -116.9375 | 32.6875 |
| City of Oceanside | -117.3125 | 33.1875 |
| Santa Fe Irrigation District | -117.1875 | 33.0625 |
| City of Del Mar | -117.3125 | 32.9375 |
| Carlsbad Municipal Water District | -117.3125 | 33.0625 |
| Yuima Municipal Water District | -116.9375 | 33.3125 |
| City of Poway | -117.0625 | 32.9375 |
| Camp Pendleton Marine Corps Base | -117.4375 | 33.3125 |
| Helix Water District | -116.9375 | 32.8125 |
| Vallecitos County Water District | -117.1875 | 33.1875 |
| Rainbow Municipal Water District | -117.1875 | 33.3125 |
| City of National City | -117.0625 | 32.6875 |
| Fallbrook Public Utility | -117.3125 | 33.4375 |
| Rincon Del Diablo Municipal Water District | -117.0625 | 33.1875 |
| South Bay Irrigation | -117.0625 | 32.5625 |
| Olivenhain Municipal Water District | -117.1875 | 33.0625 |
| Valley Center Municipal Water District | -117.0625 | 33.3125 |
| City of San Diego | -117.1875 | 32.8125 |
| San Dieguito Water District | -117.1875 | 32.9375 |
| City of Escondido | -116.9375 | 33.0625 |
| Vista Irrigation District | -117.3125 | 33.3125 |
| Padre Dam Municipal Water District | -116.8125 | 32.8125 |
| Ramona Municipal Water District | -116.8125 | 33.0625 |
| Lakeside Water District | -116.9375 | 32.9375 |

The locations are also shown in Figure C-1.

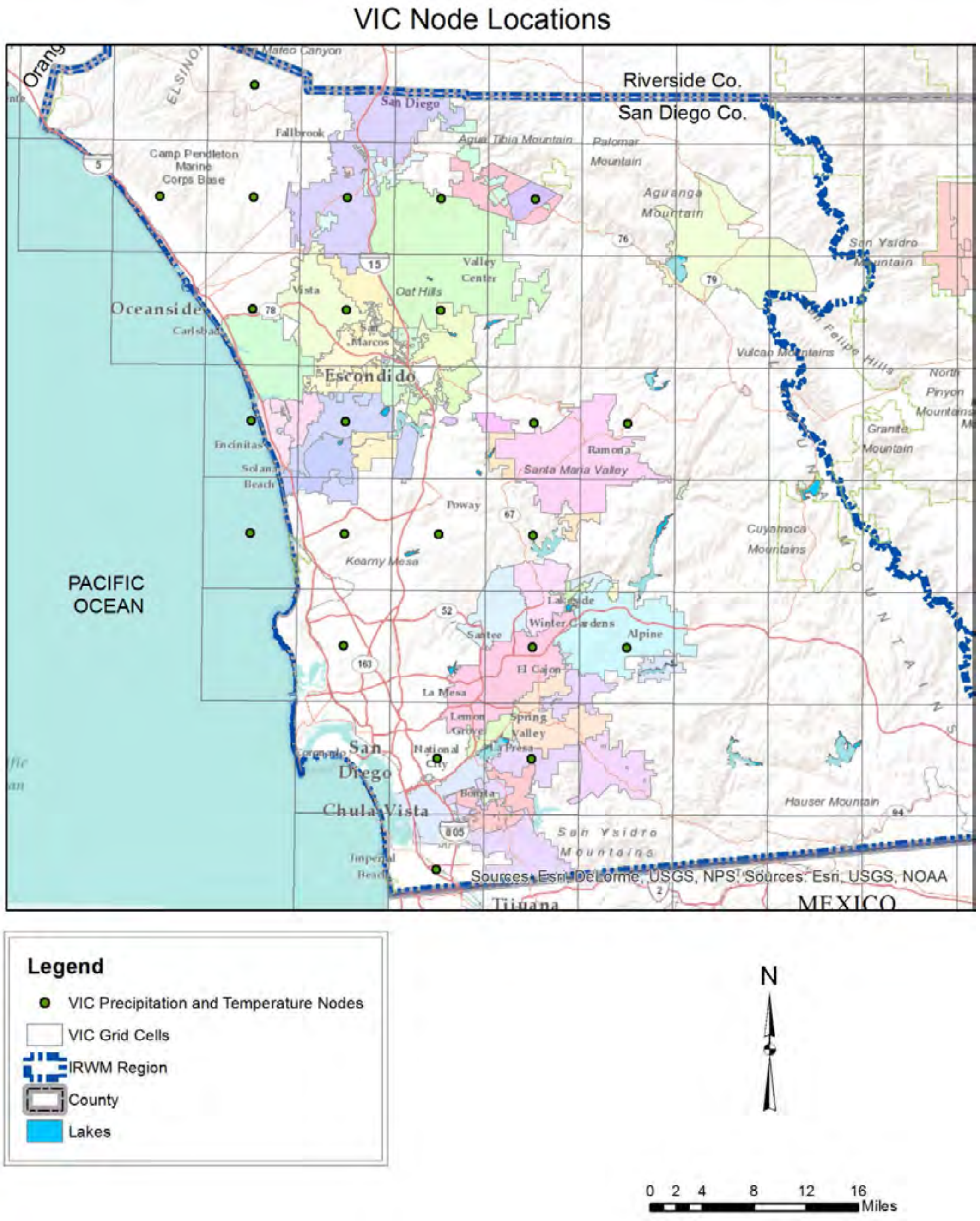

Figure C-1.—Water district representative VIC nodes.

Change factors for precipitation and temperature are calculated at each of the 24 locations for all five ensemble informed delta climate scenarios in the two future periods. The change factors are found in Table C-2 through Table C-4.

Table C-2.—Water District Precipitation Change Factors

| Agency | Period | Scenario | Precipitation (mm; Historical) | Precipitation (mm; Future) | Precipitation Change (%) |
|---|---|---|---|---|---|
| Camp Pendleton Marine Corps Base | 2020s | hot-dry | 304.1 | 268.8 | -11.6 |
| Camp Pendleton Marine Corps Base | 2020s | hot-wet | 304.1 | 343.3 | 12.9 |
| Camp Pendleton Marine Corps Base | 2020s | middle | 304.0 | 306.9 | 1.0 |
| Camp Pendleton Marine Corps Base | 2020s | warm-dry | 304.1 | 266.2 | -12.4 |
| Camp Pendleton Marine Corps Base | 2020s | warm-wet | 304.0 | 348.8 | 14.7 |
| Camp Pendleton Marine Corps Base | 2050s | hot-dry | 304.1 | 254.4 | -16.3 |
| Camp Pendleton Marine Corps Base | 2050s | hot-wet | 304.0 | 338.2 | 11.2 |
| Camp Pendleton Marine Corps Base | 2050s | middle | 304.1 | 299.6 | -1.5 |
| Camp Pendleton Marine Corps Base | 2050s | warm-dry | 304.1 | 258.9 | -14.9 |
| Camp Pendleton Marine Corps Base | 2050s | warm-wet | 304.0 | 346.2 | 13.9 |
| Carlsbad Municipal Water District | 2020s | hot-dry | 242.6 | 214.8 | -11.5 |
| Carlsbad Municipal Water District | 2020s | hot-wet | 242.6 | 273.1 | 12.6 |
| Carlsbad Municipal Water District | 2020s | middle | 242.5 | 245.4 | 1.2 |
| Carlsbad Municipal Water District | 2020s | warm-dry | 242.6 | 213.3 | -12.1 |
| Carlsbad Municipal Water District | 2020s | warm-wet | 242.5 | 276.6 | 14.0 |
| Carlsbad Municipal Water District | 2050s | hot-dry | 242.6 | 203.8 | -16.0 |
| Carlsbad Municipal Water District | 2050s | hot-wet | 242.6 | 269.9 | 11.3 |
| Carlsbad Municipal Water District | 2050s | middle | 242.6 | 238.5 | -1.7 |
| Carlsbad Municipal Water District | 2050s | warm-dry | 242.6 | 206.0 | -15.1 |
| Carlsbad Municipal Water District | 2050s | warm-wet | 242.5 | 274.6 | 13.2 |
| City of Del Mar | 2020s | hot-dry | 237.7 | 211.5 | -11.0 |
| City of Del Mar | 2020s | hot-wet | 237.7 | 266.7 | 12.2 |
| City of Del Mar | 2020s | middle | 237.7 | 241.0 | 1.4 |
| City of Del Mar | 2020s | warm-dry | 237.7 | 209.6 | -11.8 |

| Agency | Period | Scenario | Precipitation (mm; Historical) | Precipitation (mm; Future) | Precipitation Change (%) |
|---|---|---|---|---|---|
| City of Del Mar | 2020s | warm-wet | 237.7 | 270.1 | 13.6 |
| City of Del Mar | 2050s | hot-dry | 237.7 | 201.2 | -15.3 |
| City of Del Mar | 2050s | hot-wet | 237.7 | 264.6 | 11.3 |
| City of Del Mar | 2050s | middle | 237.7 | 234.0 | -1.6 |
| City of Del Mar | 2050s | warm-dry | 237.7 | 202.5 | -14.8 |
| City of Del Mar | 2050s | warm-wet | 237.7 | 267.9 | 12.7 |
| City of Escondido | 2020s | hot-dry | 399.2 | 353.8 | -11.4 |
| City of Escondido | 2020s | hot-wet | 399.2 | 441.2 | 10.5 |
| City of Escondido | 2020s | middle | 399.1 | 402.9 | 1.0 |
| City of Escondido | 2020s | warm-dry | 399.2 | 351.4 | -12.0 |
| City of Escondido | 2020s | warm-wet | 399.1 | 451.4 | 13.1 |
| City of Escondido | 2050s | hot-dry | 399.2 | 336.1 | -15.8 |
| City of Escondido | 2050s | hot-wet | 399.1 | 438.4 | 9.8 |
| City of Escondido | 2050s | middle | 399.2 | 386.6 | -3.1 |
| City of Escondido | 2050s | warm-dry | 399.2 | 338.6 | -15.2 |
| City of Escondido | 2050s | warm-wet | 399.1 | 449.1 | 12.5 |
| City of National City | 2020s | hot-dry | 263.3 | 234.4 | -11.0 |
| City of National City | 2020s | hot-wet | 263.3 | 289.4 | 9.9 |
| City of National City | 2020s | middle | 263.2 | 265.1 | 0.7 |
| City of National City | 2020s | warm-dry | 263.3 | 233.8 | -11.2 |
| City of National City | 2020s | warm-wet | 263.2 | 294.2 | 11.8 |
| City of National City | 2050s | hot-dry | 263.3 | 223.1 | -15.3 |
| City of National City | 2050s | hot-wet | 263.2 | 288.5 | 9.6 |
| City of National City | 2050s | middle | 263.3 | 255.1 | -3.1 |
| City of National City | 2050s | warm-dry | 263.3 | 226.4 | -14.0 |

| Agency | Period | Scenario | Precipitation (mm; Historical) | Precipitation (mm; Future) | Precipitation Change (%) |
|---|---|---|---|---|---|
| City of National City | 2050s | warm-wet | 263.2 | 294.1 | 11.7 |
| City of Oceanside | 2020s | hot-dry | 283.6 | 251.0 | -11.5 |
| City of Oceanside | 2020s | hot-wet | 283.6 | 319.0 | 12.5 |
| City of Oceanside | 2020s | middle | 283.5 | 286.9 | 1.2 |
| City of Oceanside | 2020s | warm-dry | 283.6 | 249.1 | -12.2 |
| City of Oceanside | 2020s | warm-wet | 283.5 | 324.2 | 14.4 |
| City of Oceanside | 2050s | hot-dry | 283.6 | 238.1 | -16.0 |
| City of Oceanside | 2050s | hot-wet | 283.5 | 315.3 | 11.2 |
| City of Oceanside | 2050s | middle | 283.6 | 278.7 | -1.7 |
| City of Oceanside | 2050s | warm-dry | 283.6 | 241.0 | -15.0 |
| City of Oceanside | 2050s | warm-wet | 283.5 | 322.1 | 13.6 |
| City of Poway | 2020s | hot-dry | 337.2 | 299.4 | -11.2 |
| City of Poway | 2020s | hot-wet | 337.2 | 372.5 | 10.5 |
| City of Poway | 2020s | middle | 337.2 | 339.8 | 0.8 |
| City of Poway | 2020s | warm-dry | 337.2 | 297.5 | -11.8 |
| City of Poway | 2020s | warm-wet | 337.1 | 380.3 | 12.8 |
| City of Poway | 2050s | hot-dry | 337.2 | 284.4 | -15.7 |
| City of Poway | 2050s | hot-wet | 337.2 | 370.1 | 9.8 |
| City of Poway | 2050s | middle | 337.2 | 327.1 | -3.0 |
| City of Poway | 2050s | warm-dry | 337.2 | 287.5 | -14.7 |
| City of Poway | 2050s | warm-wet | 337.1 | 378.8 | 12.4 |
| City of San Diego | 2020s | hot-dry | 260.8 | 232.4 | -10.9 |
| City of San Diego | 2020s | hot-wet | 260.8 | 288.1 | 10.5 |
| City of San Diego | 2020s | middle | 260.8 | 262.7 | 0.7 |
| City of San Diego | 2020s | warm-dry | 260.8 | 230.9 | -11.5 |

| Agency | Period | Scenario | Precipitation (mm; Historical) | Precipitation (mm; Future) | Precipitation Change (%) |
|---|---|---|---|---|---|
| City of San Diego | 2020s | warm-wet | 260.8 | 292.6 | 12.2 |
| City of San Diego | 2050s | hot-dry | 260.9 | 221.0 | -15.3 |
| City of San Diego | 2050s | hot-wet | 260.8 | 286.7 | 9.9 |
| City of San Diego | 2050s | middle | 260.8 | 254.0 | -2.6 |
| City of San Diego | 2050s | warm-dry | 260.8 | 224.2 | -14.0 |
| City of San Diego | 2050s | warm-wet | 260.8 | 292.1 | 12.0 |
| Fallbrook Public Utility | 2020s | hot-dry | 318.6 | 280.2 | -12.1 |
| Fallbrook Public Utility | 2020s | hot-wet | 318.6 | 360.9 | 13.3 |
| Fallbrook Public Utility | 2020s | middle | 318.6 | 321.9 | 1.1 |
| Fallbrook Public Utility | 2020s | warm-dry | 318.6 | 278.0 | -12.7 |
| Fallbrook Public Utility | 2020s | warm-wet | 318.6 | 367.9 | 15.5 |
| Fallbrook Public Utility | 2050s | hot-dry | 318.7 | 265.0 | -16.8 |
| Fallbrook Public Utility | 2050s | hot-wet | 318.6 | 355.4 | 11.6 |
| Fallbrook Public Utility | 2050s | middle | 318.6 | 313.3 | -1.7 |
| Fallbrook Public Utility | 2050s | warm-dry | 318.6 | 269.2 | -15.5 |
| Fallbrook Public Utility | 2050s | warm-wet | 318.6 | 365.1 | 14.6 |
| Helix Water District | 2020s | hot-dry | 335.7 | 298.6 | -11.1 |
| Helix Water District | 2020s | hot-wet | 335.7 | 368.1 | 9.7 |
| Helix Water District | 2020s | middle | 335.6 | 338.6 | 0.9 |
| Helix Water District | 2020s | warm-dry | 335.7 | 297.5 | -11.4 |
| Helix Water District | 2020s | warm-wet | 335.6 | 376.3 | 12.1 |
| Helix Water District | 2050s | hot-dry | 335.7 | 284.3 | -15.3 |
| Helix Water District | 2050s | hot-wet | 335.6 | 367.5 | 9.5 |
| Helix Water District | 2050s | middle | 335.7 | 324.4 | -3.4 |
| Helix Water District | 2050s | warm-dry | 335.7 | 286.8 | -14.6 |

| Agency | Period | Scenario | Precipitation (mm; Historical) | Precipitation (mm; Future) | Precipitation Change (%) |
|---|---|---|---|---|---|
| Helix Water District | 2050s | warm-wet | 335.6 | 375.4 | 11.9 |
| Lakeside Water District | 2020s | hot-dry | 375.9 | 333.9 | -11.2 |
| Lakeside Water District | 2020s | hot-wet | 375.9 | 413.0 | 9.9 |
| Lakeside Water District | 2020s | middle | 375.8 | 379.0 | 0.8 |
| Lakeside Water District | 2020s | warm-dry | 375.9 | 331.8 | -11.7 |
| Lakeside Water District | 2020s | warm-wet | 375.8 | 422.7 | 12.5 |
| Lakeside Water District | 2050s | hot-dry | 375.9 | 317.3 | -15.6 |
| Lakeside Water District | 2050s | hot-wet | 375.8 | 411.5 | 9.5 |
| Lakeside Water District | 2050s | middle | 375.9 | 363.3 | -3.3 |
| Lakeside Water District | 2050s | warm-dry | 375.9 | 319.6 | -15.0 |
| Lakeside Water District | 2050s | warm-wet | 375.8 | 420.8 | 12.0 |
| Olivenhain Municipal Water District | 2020s | hot-dry | 297.2 | 261.9 | -11.9 |
| Olivenhain Municipal Water District | 2020s | hot-wet | 297.1 | 333.2 | 12.1 |
| Olivenhain Municipal Water District | 2020s | middle | 297.1 | 300.7 | 1.2 |
| Olivenhain Municipal Water District | 2020s | warm-dry | 297.1 | 261.2 | -12.1 |
| Olivenhain Municipal Water District | 2020s | warm-wet | 297.1 | 338.8 | 14.0 |
| Olivenhain Municipal Water District | 2050s | hot-dry | 297.2 | 248.9 | -16.2 |
| Olivenhain Municipal Water District | 2050s | hot-wet | 297.1 | 330.7 | 11.3 |
| Olivenhain Municipal Water District | 2050s | middle | 297.1 | 290.6 | -2.2 |
| Olivenhain Municipal Water District | 2050s | warm-dry | 297.1 | 251.7 | -15.3 |
| Olivenhain Municipal Water District | 2050s | warm-wet | 297.1 | 337.6 | 13.6 |
| Otay Water District (East) | 2020s | hot-dry | 315.5 | 279.6 | -11.4 |
| Otay Water District (East) | 2020s | hot-wet | 315.5 | 345.6 | 9.5 |
| Otay Water District (East) | 2020s | middle | 315.5 | 318.6 | 1.0 |
| Otay Water District (East) | 2020s | warm-dry | 315.5 | 280.2 | -11.2 |

| Agency | Period | Scenario | Precipitation (mm; Historical) | Precipitation (mm; Future) | Precipitation Change (%) |
|---|---|---|---|---|---|
| Otay Water District (East) | 2020s | warm-wet | 315.5 | 353.0 | 11.9 |
| Otay Water District (East) | 2050s | hot-dry | 315.5 | 266.9 | -15.4 |
| Otay Water District (East) | 2050s | hot-wet | 315.5 | 345.8 | 9.6 |
| Otay Water District (East) | 2050s | middle | 315.5 | 304.3 | -3.5 |
| Otay Water District (East) | 2050s | warm-dry | 315.5 | 269.8 | -14.5 |
| Otay Water District (East) | 2050s | warm-wet | 315.5 | 353.2 | 12.0 |
| Padre Dam Municipal Water District | 2020s | hot-dry | 411.4 | 366.7 | -10.9 |
| Padre Dam Municipal Water District | 2020s | hot-wet | 411.4 | 448.7 | 9.1 |
| Padre Dam Municipal Water District | 2020s | middle | 411.3 | 414.2 | 0.7 |
| Padre Dam Municipal Water District | 2020s | warm-dry | 411.4 | 364.7 | -11.4 |
| Padre Dam Municipal Water District | 2020s | warm-wet | 411.3 | 458.5 | 11.5 |
| Padre Dam Municipal Water District | 2050s | hot-dry | 411.4 | 349.2 | -15.1 |
| Padre Dam Municipal Water District | 2050s | hot-wet | 411.4 | 447.7 | 8.8 |
| Padre Dam Municipal Water District | 2050s | middle | 411.4 | 396.3 | -3.7 |
| Padre Dam Municipal Water District | 2050s | warm-dry | 411.4 | 352.4 | -14.4 |
| Padre Dam Municipal Water District | 2050s | warm-wet | 411.3 | 457.2 | 11.1 |
| Rainbow Municipal Water District | 2020s | hot-dry | 347.0 | 305.7 | -11.9 |
| Rainbow Municipal Water District | 2020s | hot-wet | 347.0 | 389.5 | 12.3 |
| Rainbow Municipal Water District | 2020s | middle | 346.9 | 350.6 | 1.1 |
| Rainbow Municipal Water District | 2020s | warm-dry | 347.0 | 303.6 | -12.5 |
| Rainbow Municipal Water District | 2020s | warm-wet | 346.9 | 397.7 | 14.6 |
| Rainbow Municipal Water District | 2050s | hot-dry | 347.0 | 289.8 | -16.5 |
| Rainbow Municipal Water District | 2050s | hot-wet | 346.9 | 384.9 | 10.9 |
| Rainbow Municipal Water District | 2050s | middle | 347.0 | 339.3 | -2.2 |
| Rainbow Municipal Water District | 2050s | warm-dry | 347.0 | 293.6 | -15.4 |

| Agency | Period | Scenario | Precipitation (mm; Historical) | Precipitation (mm; Future) | Precipitation Change (%) |
|---|---|---|---|---|---|
| Rainbow Municipal Water District | 2050s | warm-wet | 346.9 | 395.2 | 13.9 |
| Ramona Municipal Water District | 2020s | hot-dry | 417.3 | 369.6 | -11.4 |
| Ramona Municipal Water District | 2020s | hot-wet | 417.3 | 459.1 | 10.0 |
| Ramona Municipal Water District | 2020s | middle | 417.2 | 420.9 | 0.9 |
| Ramona Municipal Water District | 2020s | warm-dry | 417.3 | 367.5 | -11.9 |
| Ramona Municipal Water District | 2020s | warm-wet | 417.2 | 469.6 | 12.5 |
| Ramona Municipal Water District | 2050s | hot-dry | 417.3 | 351.3 | -15.8 |
| Ramona Municipal Water District | 2050s | hot-wet | 417.3 | 455.6 | 9.2 |
| Ramona Municipal Water District | 2050s | middle | 417.3 | 402.5 | -3.5 |
| Ramona Municipal Water District | 2050s | warm-dry | 417.3 | 354.3 | -15.1 |
| Ramona Municipal Water District | 2050s | warm-wet | 417.2 | 467.4 | 12.0 |
| Rincon Del Diablo Municipal Water District | 2020s | hot-dry | 395.2 | 348.5 | -11.8 |
| Rincon Del Diablo Municipal Water District | 2020s | hot-wet | 395.2 | 441.3 | 11.7 |
| Rincon Del Diablo Municipal Water District | 2020s | middle | 395.1 | 399.3 | 1.1 |
| Rincon Del Diablo Municipal Water District | 2020s | warm-dry | 395.2 | 346.5 | -12.3 |
| Rincon Del Diablo Municipal Water District | 2020s | warm-wet | 395.1 | 450.6 | 14.0 |
| Rincon Del Diablo Municipal Water District | 2050s | hot-dry | 395.3 | 331.6 | -16.1 |
| Rincon Del Diablo Municipal Water District | 2050s | hot-wet | 395.2 | 437.1 | 10.6 |
| Rincon Del Diablo Municipal Water District | 2050s | middle | 395.2 | 384.8 | -2.6 |
| Rincon Del Diablo Municipal Water District | 2050s | warm-dry | 395.2 | 335.3 | -15.2 |
| Rincon Del Diablo Municipal Water District | 2050s | warm-wet | 395.1 | 448.7 | 13.6 |
| San Dieguito Water District | 2020s | hot-dry | 272.9 | 242.4 | -11.2 |
| San Dieguito Water District | 2020s | hot-wet | 272.9 | 304.1 | 11.4 |
| San Dieguito Water District | 2020s | middle | 272.9 | 275.9 | 1.1 |
| San Dieguito Water District | 2020s | warm-dry | 272.9 | 240.8 | -11.8 |

| Agency | Period | Scenario | Precipitation (mm; Historical) | Precipitation (mm; Future) | Precipitation Change (%) |
|---|---|---|---|---|---|
| San Dieguito Water District | 2020s | warm-wet | 272.9 | 308.9 | 13.2 |
| San Dieguito Water District | 2050s | hot-dry | 272.9 | 230.4 | -15.6 |
| San Dieguito Water District | 2050s | hot-wet | 272.9 | 302.0 | 10.7 |
| San Dieguito Water District | 2050s | middle | 272.9 | 266.8 | -2.2 |
| San Dieguito Water District | 2050s | warm-dry | 272.9 | 232.5 | -14.8 |
| San Dieguito Water District | 2050s | warm-wet | 272.9 | 307.4 | 12.7 |
| Santa Fe Irrigation District | 2020s | hot-dry | 297.2 | 261.9 | -11.9 |
| Santa Fe Irrigation District | 2020s | hot-wet | 297.1 | 333.2 | 12.1 |
| Santa Fe Irrigation District | 2020s | middle | 297.1 | 300.7 | 1.2 |
| Santa Fe Irrigation District | 2020s | warm-dry | 297.1 | 261.2 | -12.1 |
| Santa Fe Irrigation District | 2020s | warm-wet | 297.1 | 338.8 | 14.0 |
| Santa Fe Irrigation District | 2050s | hot-dry | 297.2 | 248.9 | -16.2 |
| Santa Fe Irrigation District | 2050s | hot-wet | 297.1 | 330.7 | 11.3 |
| Santa Fe Irrigation District | 2050s | middle | 297.1 | 290.6 | -2.2 |
| Santa Fe Irrigation District | 2050s | warm-dry | 297.1 | 251.7 | -15.3 |
| Santa Fe Irrigation District | 2050s | warm-wet | 297.1 | 337.6 | 13.6 |
| South Bay Irrigation | 2020s | hot-dry | 252.2 | 225.1 | -10.7 |
| South Bay Irrigation | 2020s | hot-wet | 252.2 | 275.5 | 9.2 |
| South Bay Irrigation | 2020s | middle | 252.2 | 253.5 | 0.5 |
| South Bay Irrigation | 2020s | warm-dry | 252.2 | 224.5 | -11.0 |
| South Bay Irrigation | 2020s | warm-wet | 252.2 | 279.9 | 11.0 |
| South Bay Irrigation | 2050s | hot-dry | 252.2 | 214.4 | -15.0 |
| South Bay Irrigation | 2050s | hot-wet | 252.2 | 274.9 | 9.0 |
| South Bay Irrigation | 2050s | middle | 252.2 | 243.7 | -3.4 |
| South Bay Irrigation | 2050s | warm-dry | 252.2 | 217.8 | -13.6 |

| Agency | Period | Scenario | Precipitation (mm; Historical) | Precipitation (mm; Future) | Precipitation Change (%) |
|---|---|---|---|---|---|
| South Bay Irrigation | 2050s | warm-wet | 252.1 | 280.2 | 11.1 |
| Valley Center Municipal Water District | 2020s | hot-dry | 384.3 | 338.2 | -12.0 |
| Valley Center Municipal Water District | 2020s | hot-wet | 384.3 | 429.1 | 11.7 |
| Valley Center Municipal Water District | 2020s | middle | 384.2 | 389.0 | 1.2 |
| Valley Center Municipal Water District | 2020s | warm-dry | 384.3 | 336.4 | -12.5 |
| Valley Center Municipal Water District | 2020s | warm-wet | 384.2 | 439.7 | 14.4 |
| Valley Center Municipal Water District | 2050s | hot-dry | 384.3 | 321.2 | -16.4 |
| Valley Center Municipal Water District | 2050s | hot-wet | 384.3 | 426.2 | 10.9 |
| Valley Center Municipal Water District | 2050s | middle | 384.3 | 374.3 | -2.6 |
| Valley Center Municipal Water District | 2050s | warm-dry | 384.3 | 324.1 | -15.7 |
| Valley Center Municipal Water District | 2050s | warm-wet | 384.2 | 437.6 | 13.9 |
| Vallecitos County Water District | 2020s | hot-dry | 371.6 | 326.8 | -12.0 |
| Vallecitos County Water District | 2020s | hot-wet | 371.5 | 416.2 | 12.0 |
| Vallecitos County Water District | 2020s | middle | 371.5 | 375.2 | 1.0 |
| Vallecitos County Water District | 2020s | warm-dry | 371.6 | 325.3 | -12.4 |
| Vallecitos County Water District | 2020s | warm-wet | 371.5 | 424.1 | 14.2 |
| Vallecitos County Water District | 2050s | hot-dry | 371.6 | 310.5 | -16.4 |
| Vallecitos County Water District | 2050s | hot-wet | 371.5 | 412.0 | 10.9 |
| Vallecitos County Water District | 2050s | middle | 371.5 | 362.7 | -2.4 |
| Vallecitos County Water District | 2050s | warm-dry | 371.5 | 314.9 | -15.2 |
| Vallecitos County Water District | 2050s | warm-wet | 371.5 | 422.2 | 13.6 |
| Vista Irrigation District | 2020s | hot-dry | 313.0 | 276.4 | -11.7 |
| Vista Irrigation District | 2020s | hot-wet | 313.0 | 352.4 | 12.6 |
| Vista Irrigation District | 2020s | middle | 312.9 | 316.3 | 1.1 |
| Vista Irrigation District | 2020s | warm-dry | 313.0 | 274.2 | -12.4 |

| Agency | Period | Scenario | Precipitation (mm; Historical) | Precipitation (mm; Future) | Precipitation Change (%) |
|---|---|---|---|---|---|
| Vista Irrigation District | 2020s | warm-wet | 312.9 | 358.9 | 14.7 |
| Vista Irrigation District | 2050s | hot-dry | 313.0 | 261.9 | -16.3 |
| Vista Irrigation District | 2050s | hot-wet | 312.9 | 347.7 | 11.1 |
| Vista Irrigation District | 2050s | middle | 313.0 | 307.3 | -1.8 |
| Vista Irrigation District | 2050s | warm-dry | 313.0 | 265.9 | -15.1 |
| Vista Irrigation District | 2050s | warm-wet | 312.9 | 356.6 | 14.0 |
| Yuima Municipal Water District | 2020s | hot-dry | 482.9 | 425.8 | -11.8 |
| Yuima Municipal Water District | 2020s | hot-wet | 482.8 | 536.1 | 11.0 |
| Yuima Municipal Water District | 2020s | middle | 482.8 | 488.9 | 1.3 |
| Yuima Municipal Water District | 2020s | warm-dry | 482.9 | 423.7 | -12.3 |
| Yuima Municipal Water District | 2020s | warm-wet | 482.8 | 549.9 | 13.9 |
| Yuima Municipal Water District | 2050s | hot-dry | 482.9 | 405.5 | -16.0 |
| Yuima Municipal Water District | 2050s | hot-wet | 482.8 | 534.1 | 10.6 |
| Yuima Municipal Water District | 2050s | middle | 482.8 | 468.9 | -2.9 |
| Yuima Municipal Water District | 2050s | warm-dry | 482.8 | 408.4 | -15.4 |
| Yuima Municipal Water District | 2050s | warm-wet | 482.7 | 548.5 | 13.6 |

Table C-3.—Water District Min. Temperature Change Factors

| **Agency** | **Period** | **Scenario** | **Min. Temperature (°C; Historical)** | **Min. Temperature (°C; Future)** | **Min. Temperature Change (°C)** |
|---|---|---|---|---|---|
| Camp Pendleton Marine Corps Base | 2020s | hot-dry | 10.7 | 12.0 | 1.3 |
| Camp Pendleton Marine Corps Base | 2020s | hot-wet | 10.7 | 12.2 | 1.5 |
| Camp Pendleton Marine Corps Base | 2020s | middle | 10.7 | 11.7 | 1.1 |
| Camp Pendleton Marine Corps Base | 2020s | warm-dry | 10.7 | 11.5 | 0.8 |
| Camp Pendleton Marine Corps Base | 2020s | warm-wet | 10.7 | 11.5 | 0.8 |
| Camp Pendleton Marine Corps Base | 2050s | hot-dry | 10.7 | 13.1 | 2.5 |
| Camp Pendleton Marine Corps Base | 2050s | hot-wet | 10.7 | 13.4 | 2.8 |
| Camp Pendleton Marine Corps Base | 2050s | middle | 10.7 | 12.7 | 2.0 |
| Camp Pendleton Marine Corps Base | 2050s | warm-dry | 10.7 | 12.1 | 1.4 |
| Camp Pendleton Marine Corps Base | 2050s | warm-wet | 10.7 | 12.1 | 1.4 |
| Carlsbad Municipal Water District | 2020s | hot-dry | 11.3 | 12.6 | 1.3 |
| Carlsbad Municipal Water District | 2020s | hot-wet | 11.3 | 12.8 | 1.5 |
| Carlsbad Municipal Water District | 2020s | middle | 11.3 | 12.3 | 1.1 |
| Carlsbad Municipal Water District | 2020s | warm-dry | 11.3 | 12.1 | 0.8 |
| Carlsbad Municipal Water District | 2020s | warm-wet | 11.3 | 12.1 | 0.8 |
| Carlsbad Municipal Water District | 2050s | hot-dry | 11.3 | 13.7 | 2.4 |
| Carlsbad Municipal Water District | 2050s | hot-wet | 11.3 | 14.0 | 2.7 |
| Carlsbad Municipal Water District | 2050s | middle | 11.3 | 13.3 | 2.0 |
| Carlsbad Municipal Water District | 2050s | warm-dry | 11.3 | 12.6 | 1.4 |
| Carlsbad Municipal Water District | 2050s | warm-wet | 11.3 | 12.6 | 1.4 |
| City of Del Mar | 2020s | hot-dry | 12.4 | 13.7 | 1.3 |

| Agency | Period | Scenario | Min. Temperature (°C; Historical) | Min. Temperature (°C; Future) | Min. Temperature Change (°C) |
|---|---|---|---|---|---|
| City of Del Mar | 2020s | hot-wet | 12.4 | 13.9 | 1.5 |
| City of Del Mar | 2020s | middle | 12.4 | 13.5 | 1.0 |
| City of Del Mar | 2020s | warm-dry | 12.4 | 13.2 | 0.8 |
| City of Del Mar | 2020s | warm-wet | 12.4 | 13.2 | 0.8 |
| City of Del Mar | 2050s | hot-dry | 12.4 | 14.8 | 2.4 |
| City of Del Mar | 2050s | hot-wet | 12.4 | 15.1 | 2.7 |
| City of Del Mar | 2050s | middle | 12.4 | 14.4 | 2.0 |
| City of Del Mar | 2050s | warm-dry | 12.4 | 13.7 | 1.3 |
| City of Del Mar | 2050s | warm-wet | 12.4 | 13.8 | 1.4 |
| City of Escondido | 2020s | hot-dry | 7.9 | 9.2 | 1.3 |
| City of Escondido | 2020s | hot-wet | 7.9 | 9.4 | 1.5 |
| City of Escondido | 2020s | middle | 7.9 | 9.0 | 1.1 |
| City of Escondido | 2020s | warm-dry | 7.9 | 8.7 | 0.8 |
| City of Escondido | 2020s | warm-wet | 7.9 | 8.7 | 0.9 |
| City of Escondido | 2050s | hot-dry | 7.9 | 10.4 | 2.5 |
| City of Escondido | 2050s | hot-wet | 7.9 | 10.7 | 2.8 |
| City of Escondido | 2050s | middle | 7.9 | 9.9 | 2.1 |
| City of Escondido | 2050s | warm-dry | 7.9 | 9.3 | 1.4 |
| City of Escondido | 2050s | warm-wet | 7.9 | 9.3 | 1.4 |
| City of National City | 2020s | hot-dry | 11.8 | 13.1 | 1.3 |
| City of National City | 2020s | hot-wet | 11.8 | 13.3 | 1.5 |
| City of National City | 2020s | middle | 11.8 | 12.8 | 1.1 |

| Agency | Period | Scenario | Min. Temperature (°C; Historical) | Min. Temperature (°C; Future) | Min. Temperature Change (°C) |
|---|---|---|---|---|---|
| City of National City | 2020s | warm-dry | 11.8 | 12.6 | 0.8 |
| City of National City | 2020s | warm-wet | 11.8 | 12.6 | 0.8 |
| City of National City | 2050s | hot-dry | 11.8 | 14.2 | 2.4 |
| City of National City | 2050s | hot-wet | 11.8 | 14.5 | 2.7 |
| City of National City | 2050s | middle | 11.8 | 13.8 | 2.0 |
| City of National City | 2050s | warm-dry | 11.8 | 13.1 | 1.3 |
| City of National City | 2050s | warm-wet | 11.8 | 13.2 | 1.4 |
| City of Oceanside | 2020s | hot-dry | 11.2 | 12.5 | 1.3 |
| City of Oceanside | 2020s | hot-wet | 11.2 | 12.7 | 1.5 |
| City of Oceanside | 2020s | middle | 11.2 | 12.3 | 1.1 |
| City of Oceanside | 2020s | warm-dry | 11.2 | 12.0 | 0.8 |
| City of Oceanside | 2020s | warm-wet | 11.2 | 12.0 | 0.8 |
| City of Oceanside | 2050s | hot-dry | 11.2 | 13.7 | 2.5 |
| City of Oceanside | 2050s | hot-wet | 11.2 | 14.0 | 2.8 |
| City of Oceanside | 2050s | middle | 11.2 | 13.2 | 2.0 |
| City of Oceanside | 2050s | warm-dry | 11.2 | 12.6 | 1.4 |
| City of Oceanside | 2050s | warm-wet | 11.2 | 12.6 | 1.4 |
| City of Poway | 2020s | hot-dry | 9.9 | 11.2 | 1.3 |
| City of Poway | 2020s | hot-wet | 9.9 | 11.4 | 1.5 |
| City of Poway | 2020s | middle | 9.9 | 11.0 | 1.1 |
| City of Poway | 2020s | warm-dry | 9.9 | 10.7 | 0.8 |
| City of Poway | 2020s | warm-wet | 9.9 | 10.8 | 0.8 |

| Agency | Period | Scenario | Min. Temperature (°C; Historical) | Min. Temperature (°C; Future) | Min. Temperature Change (°C) |
|---|---|---|---|---|---|
| City of Poway | 2050s | hot-dry | 9.9 | 12.4 | 2.5 |
| City of Poway | 2050s | hot-wet | 9.9 | 12.7 | 2.8 |
| City of Poway | 2050s | middle | 9.9 | 12.0 | 2.0 |
| City of Poway | 2050s | warm-dry | 9.9 | 11.3 | 1.4 |
| City of Poway | 2050s | warm-wet | 9.9 | 11.3 | 1.4 |
| City of San Diego | 2020s | hot-dry | 12.9 | 14.2 | 1.3 |
| City of San Diego | 2020s | hot-wet | 12.9 | 14.4 | 1.5 |
| City of San Diego | 2020s | middle | 12.9 | 13.9 | 1.0 |
| City of San Diego | 2020s | warm-dry | 12.9 | 13.7 | 0.8 |
| City of San Diego | 2020s | warm-wet | 12.9 | 13.7 | 0.8 |
| City of San Diego | 2050s | hot-dry | 12.9 | 15.3 | 2.4 |
| City of San Diego | 2050s | hot-wet | 12.9 | 15.6 | 2.7 |
| City of San Diego | 2050s | middle | 12.9 | 14.9 | 2.0 |
| City of San Diego | 2050s | warm-dry | 12.9 | 14.2 | 1.3 |
| City of San Diego | 2050s | warm-wet | 12.9 | 14.3 | 1.4 |
| Fallbrook Public Utility | 2020s | hot-dry | 9.4 | 10.7 | 1.3 |
| Fallbrook Public Utility | 2020s | hot-wet | 9.4 | 10.9 | 1.5 |
| Fallbrook Public Utility | 2020s | middle | 9.4 | 10.5 | 1.1 |
| Fallbrook Public Utility | 2020s | warm-dry | 9.4 | 10.2 | 0.8 |
| Fallbrook Public Utility | 2020s | warm-wet | 9.4 | 10.2 | 0.8 |
| Fallbrook Public Utility | 2050s | hot-dry | 9.4 | 11.9 | 2.5 |
| Fallbrook Public Utility | 2050s | hot-wet | 9.4 | 12.2 | 2.8 |

| Agency | Period | Scenario | Min. Temperature (°C; Historical) | Min. Temperature (°C; Future) | Min. Temperature Change (°C) |
|---|---|---|---|---|---|
| Fallbrook Public Utility | 2050s | middle | 9.4 | 11.4 | 2.1 |
| Fallbrook Public Utility | 2050s | warm-dry | 9.4 | 10.8 | 1.4 |
| Fallbrook Public Utility | 2050s | warm-wet | 9.4 | 10.8 | 1.4 |
| Helix Water District | 2020s | hot-dry | 10.3 | 11.6 | 1.3 |
| Helix Water District | 2020s | hot-wet | 10.3 | 11.8 | 1.5 |
| Helix Water District | 2020s | middle | 10.3 | 11.4 | 1.1 |
| Helix Water District | 2020s | warm-dry | 10.3 | 11.1 | 0.8 |
| Helix Water District | 2020s | warm-wet | 10.3 | 11.1 | 0.8 |
| Helix Water District | 2050s | hot-dry | 10.3 | 12.8 | 2.5 |
| Helix Water District | 2050s | hot-wet | 10.3 | 13.1 | 2.8 |
| Helix Water District | 2050s | middle | 10.3 | 12.3 | 2.0 |
| Helix Water District | 2050s | warm-dry | 10.3 | 11.7 | 1.4 |
| Helix Water District | 2050s | warm-wet | 10.3 | 11.7 | 1.4 |
| Lakeside Water District | 2020s | hot-dry | 8.8 | 10.2 | 1.3 |
| Lakeside Water District | 2020s | hot-wet | 8.8 | 10.3 | 1.5 |
| Lakeside Water District | 2020s | middle | 8.8 | 9.9 | 1.1 |
| Lakeside Water District | 2020s | warm-dry | 8.8 | 9.6 | 0.8 |
| Lakeside Water District | 2020s | warm-wet | 8.8 | 9.7 | 0.8 |
| Lakeside Water District | 2050s | hot-dry | 8.8 | 11.3 | 2.5 |
| Lakeside Water District | 2050s | hot-wet | 8.8 | 11.6 | 2.8 |
| Lakeside Water District | 2050s | middle | 8.8 | 10.9 | 2.1 |
| Lakeside Water District | 2050s | warm-dry | 8.8 | 10.2 | 1.4 |

| Agency | Period | Scenario | Min. Temperature (°C; Historical) | Min. Temperature (°C; Future) | Min. Temperature Change (°C) |
|---|---|---|---|---|---|
| Lakeside Water District | 2050s | warm-wet | 8.8 | 10.2 | 1.4 |
| Olivenhain Municipal Water District | 2020s | hot-dry | 10.4 | 11.7 | 1.3 |
| Olivenhain Municipal Water District | 2020s | hot-wet | 10.4 | 11.9 | 1.5 |
| Olivenhain Municipal Water District | 2020s | middle | 10.4 | 11.4 | 1.1 |
| Olivenhain Municipal Water District | 2020s | warm-dry | 10.4 | 11.2 | 0.8 |
| Olivenhain Municipal Water District | 2020s | warm-wet | 10.4 | 11.2 | 0.8 |
| Olivenhain Municipal Water District | 2050s | hot-dry | 10.4 | 12.8 | 2.5 |
| Olivenhain Municipal Water District | 2050s | hot-wet | 10.4 | 13.1 | 2.8 |
| Olivenhain Municipal Water District | 2050s | middle | 10.4 | 12.4 | 2.0 |
| Olivenhain Municipal Water District | 2050s | warm-dry | 10.4 | 11.7 | 1.4 |
| Olivenhain Municipal Water District | 2050s | warm-wet | 10.4 | 11.8 | 1.4 |
| Otay Water District (East) | 2020s | hot-dry | 10.7 | 12.0 | 1.3 |
| Otay Water District (East) | 2020s | hot-wet | 10.7 | 12.2 | 1.5 |
| Otay Water District (East) | 2020s | middle | 10.7 | 11.8 | 1.1 |
| Otay Water District (East) | 2020s | warm-dry | 10.7 | 11.5 | 0.8 |
| Otay Water District (East) | 2020s | warm-wet | 10.7 | 11.6 | 0.8 |
| Otay Water District (East) | 2050s | hot-dry | 10.7 | 13.2 | 2.5 |
| Otay Water District (East) | 2050s | hot-wet | 10.7 | 13.5 | 2.8 |
| Otay Water District (East) | 2050s | middle | 10.7 | 12.8 | 2.0 |
| Otay Water District (East) | 2050s | warm-dry | 10.7 | 12.1 | 1.4 |
| Otay Water District (East) | 2050s | warm-wet | 10.7 | 12.1 | 1.4 |
| Padre Dam Municipal Water District | 2020s | hot-dry | 9.8 | 11.1 | 1.3 |

| Agency | Period | Scenario | Min. Temperature (°C; Historical) | Min. Temperature (°C; Future) | Min. Temperature Change (°C) |
|---|---|---|---|---|---|
| Padre Dam Municipal Water District | 2020s | hot-wet | 9.8 | 11.3 | 1.5 |
| Padre Dam Municipal Water District | 2020s | middle | 9.8 | 10.9 | 1.1 |
| Padre Dam Municipal Water District | 2020s | warm-dry | 9.8 | 10.6 | 0.8 |
| Padre Dam Municipal Water District | 2020s | warm-wet | 9.8 | 10.6 | 0.9 |
| Padre Dam Municipal Water District | 2050s | hot-dry | 9.8 | 12.3 | 2.5 |
| Padre Dam Municipal Water District | 2050s | hot-wet | 9.8 | 12.6 | 2.8 |
| Padre Dam Municipal Water District | 2050s | middle | 9.8 | 11.8 | 2.1 |
| Padre Dam Municipal Water District | 2050s | warm-dry | 9.8 | 11.1 | 1.4 |
| Padre Dam Municipal Water District | 2050s | warm-wet | 9.8 | 11.2 | 1.4 |
| Rainbow Municipal Water District | 2020s | hot-dry | 11.0 | 12.4 | 1.3 |
| Rainbow Municipal Water District | 2020s | hot-wet | 11.0 | 12.6 | 1.5 |
| Rainbow Municipal Water District | 2020s | middle | 11.0 | 12.1 | 1.1 |
| Rainbow Municipal Water District | 2020s | warm-dry | 11.0 | 11.9 | 0.8 |
| Rainbow Municipal Water District | 2020s | warm-wet | 11.0 | 11.9 | 0.8 |
| Rainbow Municipal Water District | 2050s | hot-dry | 11.0 | 13.5 | 2.5 |
| Rainbow Municipal Water District | 2050s | hot-wet | 11.0 | 13.9 | 2.8 |
| Rainbow Municipal Water District | 2050s | middle | 11.0 | 13.1 | 2.1 |
| Rainbow Municipal Water District | 2050s | warm-dry | 11.0 | 12.4 | 1.4 |
| Rainbow Municipal Water District | 2050s | warm-wet | 11.0 | 12.5 | 1.4 |
| Ramona Municipal Water District | 2020s | hot-dry | 6.9 | 8.2 | 1.4 |
| Ramona Municipal Water District | 2020s | hot-wet | 6.9 | 8.4 | 1.5 |
| Ramona Municipal Water District | 2020s | middle | 6.9 | 8.0 | 1.1 |

| Agency | Period | Scenario | Min. Temperature (°C; Historical) | Min. Temperature (°C; Future) | Min. Temperature Change (°C) |
|---|---|---|---|---|---|
| Ramona Municipal Water District | 2020s | warm-dry | 6.9 | 7.7 | 0.8 |
| Ramona Municipal Water District | 2020s | warm-wet | 6.9 | 7.7 | 0.9 |
| Ramona Municipal Water District | 2050s | hot-dry | 6.9 | 9.4 | 2.5 |
| Ramona Municipal Water District | 2050s | hot-wet | 6.9 | 9.7 | 2.9 |
| Ramona Municipal Water District | 2050s | middle | 6.9 | 9.0 | 2.1 |
| Ramona Municipal Water District | 2050s | warm-dry | 6.9 | 8.3 | 1.4 |
| Ramona Municipal Water District | 2050s | warm-wet | 6.9 | 8.3 | 1.4 |
| Rincon Del Diablo Municipal Water District | 2020s | hot-dry | 8.9 | 10.2 | 1.3 |
| Rincon Del Diablo Municipal Water District | 2020s | hot-wet | 8.9 | 10.4 | 1.5 |
| Rincon Del Diablo Municipal Water District | 2020s | middle | 8.9 | 10.0 | 1.1 |
| Rincon Del Diablo Municipal Water District | 2020s | warm-dry | 8.9 | 9.7 | 0.8 |
| Rincon Del Diablo Municipal Water District | 2020s | warm-wet | 8.9 | 9.7 | 0.8 |
| Rincon Del Diablo Municipal Water District | 2050s | hot-dry | 8.9 | 11.4 | 2.5 |
| Rincon Del Diablo Municipal Water District | 2050s | hot-wet | 8.9 | 11.7 | 2.8 |
| Rincon Del Diablo Municipal Water District | 2050s | middle | 8.9 | 11.0 | 2.1 |
| Rincon Del Diablo Municipal Water District | 2050s | warm-dry | 8.9 | 10.3 | 1.4 |
| Rincon Del Diablo Municipal Water District | 2050s | warm-wet | 8.9 | 10.3 | 1.4 |
| San Dieguito Water District | 2020s | hot-dry | 11.8 | 13.1 | 1.3 |
| San Dieguito Water District | 2020s | hot-wet | 11.8 | 13.3 | 1.5 |
| San Dieguito Water District | 2020s | middle | 11.8 | 12.8 | 1.1 |
| San Dieguito Water District | 2020s | warm-dry | 11.8 | 12.6 | 0.8 |
| San Dieguito Water District | 2020s | warm-wet | 11.8 | 12.6 | 0.8 |

| Agency | Period | Scenario | Min. Temperature (°C; Historical) | Min. Temperature (°C; Future) | Min. Temperature Change (°C) |
|---|---|---|---|---|---|
| San Dieguito Water District | 2050s | hot-dry | 11.8 | 14.2 | 2.5 |
| San Dieguito Water District | 2050s | hot-wet | 11.8 | 14.5 | 2.7 |
| San Dieguito Water District | 2050s | middle | 11.8 | 13.8 | 2.0 |
| San Dieguito Water District | 2050s | warm-dry | 11.8 | 13.1 | 1.4 |
| San Dieguito Water District | 2050s | warm-wet | 11.8 | 13.2 | 1.4 |
| Santa Fe Irrigation District | 2020s | hot-dry | 10.4 | 11.7 | 1.3 |
| Santa Fe Irrigation District | 2020s | hot-wet | 10.4 | 11.9 | 1.5 |
| Santa Fe Irrigation District | 2020s | middle | 10.4 | 11.4 | 1.1 |
| Santa Fe Irrigation District | 2020s | warm-dry | 10.4 | 11.2 | 0.8 |
| Santa Fe Irrigation District | 2020s | warm-wet | 10.4 | 11.2 | 0.8 |
| Santa Fe Irrigation District | 2050s | hot-dry | 10.4 | 12.8 | 2.5 |
| Santa Fe Irrigation District | 2050s | hot-wet | 10.4 | 13.1 | 2.8 |
| Santa Fe Irrigation District | 2050s | middle | 10.4 | 12.4 | 2.0 |
| Santa Fe Irrigation District | 2050s | warm-dry | 10.4 | 11.7 | 1.4 |
| Santa Fe Irrigation District | 2050s | warm-wet | 10.4 | 11.8 | 1.4 |
| South Bay Irrigation | 2020s | hot-dry | 12.2 | 13.4 | 1.3 |
| South Bay Irrigation | 2020s | hot-wet | 12.2 | 13.6 | 1.5 |
| South Bay Irrigation | 2020s | middle | 12.2 | 13.2 | 1.0 |
| South Bay Irrigation | 2020s | warm-dry | 12.2 | 12.9 | 0.8 |
| South Bay Irrigation | 2020s | warm-wet | 12.2 | 13.0 | 0.8 |
| South Bay Irrigation | 2050s | hot-dry | 12.2 | 14.6 | 2.4 |
| South Bay Irrigation | 2050s | hot-wet | 12.2 | 14.9 | 2.7 |

| Agency | Period | Scenario | Min. Temperature (°C; Historical) | Min. Temperature (°C; Future) | Min. Temperature Change (°C) |
|---|---|---|---|---|---|
| South Bay Irrigation | 2050s | middle | 12.2 | 14.1 | 2.0 |
| South Bay Irrigation | 2050s | warm-dry | 12.2 | 13.5 | 1.3 |
| South Bay Irrigation | 2050s | warm-wet | 12.2 | 13.5 | 1.3 |
| Valley Center Municipal Water District | 2020s | hot-dry | 10.2 | 11.5 | 1.3 |
| Valley Center Municipal Water District | 2020s | hot-wet | 10.2 | 11.7 | 1.5 |
| Valley Center Municipal Water District | 2020s | middle | 10.2 | 11.3 | 1.1 |
| Valley Center Municipal Water District | 2020s | warm-dry | 10.2 | 11.0 | 0.8 |
| Valley Center Municipal Water District | 2020s | warm-wet | 10.2 | 11.0 | 0.8 |
| Valley Center Municipal Water District | 2050s | hot-dry | 10.2 | 12.7 | 2.5 |
| Valley Center Municipal Water District | 2050s | hot-wet | 10.2 | 13.0 | 2.8 |
| Valley Center Municipal Water District | 2050s | middle | 10.2 | 12.3 | 2.0 |
| Valley Center Municipal Water District | 2050s | warm-dry | 10.2 | 11.6 | 1.4 |
| Valley Center Municipal Water District | 2050s | warm-wet | 10.2 | 11.6 | 1.4 |
| Vallecitos County Water District | 2020s | hot-dry | 10.9 | 12.2 | 1.4 |
| Vallecitos County Water District | 2020s | hot-wet | 10.9 | 12.4 | 1.5 |
| Vallecitos County Water District | 2020s | middle | 10.9 | 12.0 | 1.1 |
| Vallecitos County Water District | 2020s | warm-dry | 10.9 | 11.7 | 0.8 |
| Vallecitos County Water District | 2020s | warm-wet | 10.9 | 11.7 | 0.9 |
| Vallecitos County Water District | 2050s | hot-dry | 10.9 | 13.4 | 2.5 |
| Vallecitos County Water District | 2050s | hot-wet | 10.9 | 13.7 | 2.9 |
| Vallecitos County Water District | 2050s | middle | 10.9 | 13.0 | 2.1 |
| Vallecitos County Water District | 2050s | warm-dry | 10.9 | 12.3 | 1.4 |

| Agency | Period | Scenario | Min. Temperature (°C; Historical) | Min. Temperature (°C; Future) | Min. Temperature Change (°C) |
|---|---|---|---|---|---|
| Vallecitos County Water District | 2050s | warm-wet | 10.9 | 12.3 | 1.4 |
| Vista Irrigation District | 2020s | hot-dry | 11.0 | 12.4 | 1.3 |
| Vista Irrigation District | 2020s | hot-wet | 11.0 | 12.6 | 1.5 |
| Vista Irrigation District | 2020s | middle | 11.0 | 12.1 | 1.1 |
| Vista Irrigation District | 2020s | warm-dry | 11.0 | 11.9 | 0.8 |
| Vista Irrigation District | 2020s | warm-wet | 11.0 | 11.9 | 0.8 |
| Vista Irrigation District | 2050s | hot-dry | 11.0 | 13.5 | 2.5 |
| Vista Irrigation District | 2050s | hot-wet | 11.0 | 13.8 | 2.8 |
| Vista Irrigation District | 2050s | middle | 11.0 | 13.1 | 2.0 |
| Vista Irrigation District | 2050s | warm-dry | 11.0 | 12.4 | 1.4 |
| Vista Irrigation District | 2050s | warm-wet | 11.0 | 12.5 | 1.4 |
| Yuima Municipal Water District | 2020s | hot-dry | 9.4 | 10.8 | 1.4 |
| Yuima Municipal Water District | 2020s | hot-wet | 9.4 | 11.0 | 1.6 |
| Yuima Municipal Water District | 2020s | middle | 9.4 | 10.6 | 1.1 |
| Yuima Municipal Water District | 2020s | warm-dry | 9.4 | 10.3 | 0.8 |
| Yuima Municipal Water District | 2020s | warm-wet | 9.4 | 10.3 | 0.9 |
| Yuima Municipal Water District | 2050s | hot-dry | 9.4 | 12.0 | 2.6 |
| Yuima Municipal Water District | 2050s | hot-wet | 9.4 | 12.3 | 2.9 |
| Yuima Municipal Water District | 2050s | middle | 9.4 | 11.5 | 2.1 |
| Yuima Municipal Water District | 2050s | warm-dry | 9.4 | 10.9 | 1.4 |
| Yuima Municipal Water District | 2050s | warm-wet | 9.4 | 10.9 | 1.4 |

Table C-4.—Water District Max. Temperature Change Factors

| Agency | Period | Scenario | Max. Temperature (°C; Historical) | Max. Temperature (°C; Future) | Max. Temperature Change (°C) |
|---|---|---|---|---|---|
| Camp Pendleton Marine Corps Base | 2020s | hot-dry | 21.4 | 22.9 | 1.5 |
| Camp Pendleton Marine Corps Base | 2020s | hot-wet | 21.4 | 22.9 | 1.5 |
| Camp Pendleton Marine Corps Base | 2020s | middle | 21.4 | 22.6 | 1.2 |
| Camp Pendleton Marine Corps Base | 2020s | warm-dry | 21.4 | 22.3 | 0.9 |
| Camp Pendleton Marine Corps Base | 2020s | warm-wet | 21.4 | 22.2 | 0.8 |
| Camp Pendleton Marine Corps Base | 2050s | hot-dry | 21.4 | 24.1 | 2.7 |
| Camp Pendleton Marine Corps Base | 2050s | hot-wet | 21.4 | 24.1 | 2.7 |
| Camp Pendleton Marine Corps Base | 2050s | middle | 21.4 | 23.5 | 2.1 |
| Camp Pendleton Marine Corps Base | 2050s | warm-dry | 21.4 | 22.9 | 1.5 |
| Camp Pendleton Marine Corps Base | 2050s | warm-wet | 21.4 | 22.7 | 1.3 |
| Carlsbad Municipal Water District | 2020s | hot-dry | 23.4 | 24.9 | 1.5 |
| Carlsbad Municipal Water District | 2020s | hot-wet | 23.4 | 24.9 | 1.5 |
| Carlsbad Municipal Water District | 2020s | middle | 23.4 | 24.5 | 1.2 |
| Carlsbad Municipal Water District | 2020s | warm-dry | 23.4 | 24.3 | 0.9 |
| Carlsbad Municipal Water District | 2020s | warm-wet | 23.4 | 24.2 | 0.8 |
| Carlsbad Municipal Water District | 2050s | hot-dry | 23.4 | 26.1 | 2.7 |
| Carlsbad Municipal Water District | 2050s | hot-wet | 23.4 | 26.1 | 2.7 |
| Carlsbad Municipal Water District | 2050s | middle | 23.4 | 25.5 | 2.1 |
| Carlsbad Municipal Water District | 2050s | warm-dry | 23.4 | 24.8 | 1.5 |
| Carlsbad Municipal Water District | 2050s | warm-wet | 23.4 | 24.6 | 1.3 |
| City of Del Mar | 2020s | hot-dry | 23.0 | 24.5 | 1.5 |

| Agency | Period | Scenario | Max. Temperature (°C; Historical) | Max. Temperature (°C; Future) | Max. Temperature Change (°C) |
|---|---|---|---|---|---|
| City of Del Mar | 2020s | hot-wet | 23.0 | 24.5 | 1.5 |
| City of Del Mar | 2020s | middle | 23.0 | 24.1 | 1.1 |
| City of Del Mar | 2020s | warm-dry | 23.0 | 23.9 | 0.9 |
| City of Del Mar | 2020s | warm-wet | 23.0 | 23.8 | 0.8 |
| City of Del Mar | 2050s | hot-dry | 23.0 | 25.7 | 2.7 |
| City of Del Mar | 2050s | hot-wet | 23.0 | 25.7 | 2.7 |
| City of Del Mar | 2050s | middle | 23.0 | 25.1 | 2.1 |
| City of Del Mar | 2050s | warm-dry | 23.0 | 24.4 | 1.4 |
| City of Del Mar | 2050s | warm-wet | 23.0 | 24.3 | 1.3 |
| City of Escondido | 2020s | hot-dry | 25.0 | 26.6 | 1.6 |
| City of Escondido | 2020s | hot-wet | 25.0 | 26.6 | 1.5 |
| City of Escondido | 2020s | middle | 25.0 | 26.3 | 1.2 |
| City of Escondido | 2020s | warm-dry | 25.0 | 26.0 | 0.9 |
| City of Escondido | 2020s | warm-wet | 25.0 | 25.9 | 0.8 |
| City of Escondido | 2050s | hot-dry | 25.0 | 27.8 | 2.8 |
| City of Escondido | 2050s | hot-wet | 25.0 | 27.8 | 2.8 |
| City of Escondido | 2050s | middle | 25.0 | 27.2 | 2.2 |
| City of Escondido | 2050s | warm-dry | 25.0 | 26.6 | 1.5 |
| City of Escondido | 2050s | warm-wet | 25.0 | 26.4 | 1.3 |
| City of National City | 2020s | hot-dry | 22.1 | 23.6 | 1.5 |
| City of National City | 2020s | hot-wet | 22.1 | 23.6 | 1.5 |
| City of National City | 2020s | middle | 22.1 | 23.2 | 1.1 |

| Agency | Period | Scenario | Max. Temperature (°C; Historical) | Max. Temperature (°C; Future) | Max. Temperature Change (°C) |
|---|---|---|---|---|---|
| City of National City | 2020s | warm-dry | 22.1 | 23.0 | 0.9 |
| City of National City | 2020s | warm-wet | 22.1 | 22.9 | 0.8 |
| City of National City | 2050s | hot-dry | 22.1 | 24.7 | 2.7 |
| City of National City | 2050s | hot-wet | 22.1 | 24.8 | 2.7 |
| City of National City | 2050s | middle | 22.1 | 24.2 | 2.1 |
| City of National City | 2050s | warm-dry | 22.1 | 23.5 | 1.4 |
| City of National City | 2050s | warm-wet | 22.1 | 23.3 | 1.3 |
| City of Oceanside | 2020s | hot-dry | 22.3 | 23.8 | 1.5 |
| City of Oceanside | 2020s | hot-wet | 22.3 | 23.8 | 1.5 |
| City of Oceanside | 2020s | middle | 22.3 | 23.5 | 1.2 |
| City of Oceanside | 2020s | warm-dry | 22.3 | 23.2 | 0.9 |
| City of Oceanside | 2020s | warm-wet | 22.3 | 23.1 | 0.8 |
| City of Oceanside | 2050s | hot-dry | 22.3 | 25.1 | 2.7 |
| City of Oceanside | 2050s | hot-wet | 22.3 | 25.1 | 2.7 |
| City of Oceanside | 2050s | middle | 22.3 | 24.5 | 2.1 |
| City of Oceanside | 2050s | warm-dry | 22.3 | 23.8 | 1.5 |
| City of Oceanside | 2050s | warm-wet | 22.3 | 23.6 | 1.3 |
| City of Poway | 2020s | hot-dry | 24.8 | 26.3 | 1.5 |
| City of Poway | 2020s | hot-wet | 24.8 | 26.3 | 1.5 |
| City of Poway | 2020s | middle | 24.8 | 26.0 | 1.2 |
| City of Poway | 2020s | warm-dry | 24.8 | 25.7 | 0.9 |
| City of Poway | 2020s | warm-wet | 24.8 | 25.6 | 0.8 |

| Agency | Period | Scenario | Max. Temperature (°C; Historical) | Max. Temperature (°C; Future) | Max. Temperature Change (°C) |
|---|---|---|---|---|---|
| City of Poway | 2050s | hot-dry | 24.8 | 27.5 | 2.7 |
| City of Poway | 2050s | hot-wet | 24.8 | 27.5 | 2.7 |
| City of Poway | 2050s | middle | 24.8 | 26.9 | 2.1 |
| City of Poway | 2050s | warm-dry | 24.8 | 26.3 | 1.5 |
| City of Poway | 2050s | warm-wet | 24.8 | 26.1 | 1.3 |
| City of San Diego | 2020s | hot-dry | 22.0 | 23.5 | 1.5 |
| City of San Diego | 2020s | hot-wet | 22.0 | 23.5 | 1.5 |
| City of San Diego | 2020s | middle | 22.0 | 23.2 | 1.1 |
| City of San Diego | 2020s | warm-dry | 22.0 | 22.9 | 0.9 |
| City of San Diego | 2020s | warm-wet | 22.0 | 22.8 | 0.8 |
| City of San Diego | 2050s | hot-dry | 22.0 | 24.7 | 2.7 |
| City of San Diego | 2050s | hot-wet | 22.0 | 24.7 | 2.7 |
| City of San Diego | 2050s | middle | 22.0 | 24.1 | 2.1 |
| City of San Diego | 2050s | warm-dry | 22.0 | 23.5 | 1.4 |
| City of San Diego | 2050s | warm-wet | 22.0 | 23.3 | 1.3 |
| Fallbrook Public Utility | 2020s | hot-dry | 23.5 | 25.0 | 1.6 |
| Fallbrook Public Utility | 2020s | hot-wet | 23.5 | 25.0 | 1.5 |
| Fallbrook Public Utility | 2020s | middle | 23.5 | 24.7 | 1.2 |
| Fallbrook Public Utility | 2020s | warm-dry | 23.5 | 24.4 | 1.0 |
| Fallbrook Public Utility | 2020s | warm-wet | 23.5 | 24.3 | 0.8 |
| Fallbrook Public Utility | 2050s | hot-dry | 23.5 | 26.3 | 2.8 |
| Fallbrook Public Utility | 2050s | hot-wet | 23.5 | 26.2 | 2.8 |

| Agency | Period | Scenario | Max. Temperature (°C; Historical) | Max. Temperature (°C; Future) | Max. Temperature Change (°C) |
|---|---|---|---|---|---|
| Fallbrook Public Utility | 2050s | middle | 23.5 | 25.6 | 2.2 |
| Fallbrook Public Utility | 2050s | warm-dry | 23.5 | 25.0 | 1.5 |
| Fallbrook Public Utility | 2050s | warm-wet | 23.5 | 24.8 | 1.3 |
| Helix Water District | 2020s | hot-dry | 24.9 | 26.4 | 1.5 |
| Helix Water District | 2020s | hot-wet | 24.9 | 26.4 | 1.5 |
| Helix Water District | 2020s | middle | 24.9 | 26.1 | 1.2 |
| Helix Water District | 2020s | warm-dry | 24.9 | 25.8 | 0.9 |
| Helix Water District | 2020s | warm-wet | 24.9 | 25.7 | 0.8 |
| Helix Water District | 2050s | hot-dry | 24.9 | 27.6 | 2.7 |
| Helix Water District | 2050s | hot-wet | 24.9 | 27.6 | 2.7 |
| Helix Water District | 2050s | middle | 24.9 | 27.0 | 2.1 |
| Helix Water District | 2050s | warm-dry | 24.9 | 26.4 | 1.5 |
| Helix Water District | 2050s | warm-wet | 24.9 | 26.2 | 1.3 |
| Lakeside Water District | 2020s | hot-dry | 25.2 | 26.7 | 1.5 |
| Lakeside Water District | 2020s | hot-wet | 25.2 | 26.7 | 1.5 |
| Lakeside Water District | 2020s | middle | 25.2 | 26.4 | 1.2 |
| Lakeside Water District | 2020s | warm-dry | 25.2 | 26.1 | 0.9 |
| Lakeside Water District | 2020s | warm-wet | 25.2 | 26.0 | 0.8 |
| Lakeside Water District | 2050s | hot-dry | 25.2 | 27.9 | 2.8 |
| Lakeside Water District | 2050s | hot-wet | 25.2 | 28.0 | 2.8 |
| Lakeside Water District | 2050s | middle | 25.2 | 27.4 | 2.2 |
| Lakeside Water District | 2050s | warm-dry | 25.2 | 26.7 | 1.5 |

| Agency | Period | Scenario | Max. Temperature (°C; Historical) | Max. Temperature (°C; Future) | Max. Temperature Change (°C) |
|---|---|---|---|---|---|
| Lakeside Water District | 2050s | warm-wet | 25.2 | 26.5 | 1.3 |
| Olivenhain Municipal Water District | 2020s | hot-dry | 24.5 | 26.1 | 1.5 |
| Olivenhain Municipal Water District | 2020s | hot-wet | 24.5 | 26.0 | 1.5 |
| Olivenhain Municipal Water District | 2020s | middle | 24.5 | 25.7 | 1.2 |
| Olivenhain Municipal Water District | 2020s | warm-dry | 24.5 | 25.4 | 0.9 |
| Olivenhain Municipal Water District | 2020s | warm-wet | 24.5 | 25.3 | 0.8 |
| Olivenhain Municipal Water District | 2050s | hot-dry | 24.5 | 27.3 | 2.7 |
| Olivenhain Municipal Water District | 2050s | hot-wet | 24.5 | 27.3 | 2.7 |
| Olivenhain Municipal Water District | 2050s | middle | 24.5 | 26.7 | 2.1 |
| Olivenhain Municipal Water District | 2050s | warm-dry | 24.5 | 26.0 | 1.5 |
| Olivenhain Municipal Water District | 2050s | warm-wet | 24.5 | 25.8 | 1.3 |
| Otay Water District (East) | 2020s | hot-dry | 22.5 | 24.0 | 1.5 |
| Otay Water District (East) | 2020s | hot-wet | 22.5 | 24.0 | 1.5 |
| Otay Water District (East) | 2020s | middle | 22.5 | 23.7 | 1.2 |
| Otay Water District (East) | 2020s | warm-dry | 22.5 | 23.4 | 0.9 |
| Otay Water District (East) | 2020s | warm-wet | 22.5 | 23.3 | 0.8 |
| Otay Water District (East) | 2050s | hot-dry | 22.5 | 25.2 | 2.7 |
| Otay Water District (East) | 2050s | hot-wet | 22.5 | 25.2 | 2.7 |
| Otay Water District (East) | 2050s | middle | 22.5 | 24.6 | 2.1 |
| Otay Water District (East) | 2050s | warm-dry | 22.5 | 24.0 | 1.5 |
| Otay Water District (East) | 2050s | warm-wet | 22.5 | 23.8 | 1.3 |
| Padre Dam Municipal Water District | 2020s | hot-dry | 25.1 | 26.7 | 1.5 |

| Agency | Period | Scenario | Max. Temperature (°C; Historical) | Max. Temperature (°C; Future) | Max. Temperature Change (°C) |
|---|---|---|---|---|---|
| Padre Dam Municipal Water District | 2020s | hot-wet | 25.1 | 26.6 | 1.5 |
| Padre Dam Municipal Water District | 2020s | middle | 25.1 | 26.3 | 1.2 |
| Padre Dam Municipal Water District | 2020s | warm-dry | 25.1 | 26.0 | 0.9 |
| Padre Dam Municipal Water District | 2020s | warm-wet | 25.1 | 25.9 | 0.8 |
| Padre Dam Municipal Water District | 2050s | hot-dry | 25.1 | 27.9 | 2.7 |
| Padre Dam Municipal Water District | 2050s | hot-wet | 25.1 | 27.9 | 2.8 |
| Padre Dam Municipal Water District | 2050s | middle | 25.1 | 27.3 | 2.2 |
| Padre Dam Municipal Water District | 2050s | warm-dry | 25.1 | 26.6 | 1.5 |
| Padre Dam Municipal Water District | 2050s | warm-wet | 25.1 | 26.4 | 1.3 |
| Rainbow Municipal Water District | 2020s | hot-dry | 23.6 | 25.2 | 1.6 |
| Rainbow Municipal Water District | 2020s | hot-wet | 23.6 | 25.2 | 1.5 |
| Rainbow Municipal Water District | 2020s | middle | 23.6 | 24.8 | 1.2 |
| Rainbow Municipal Water District | 2020s | warm-dry | 23.6 | 24.6 | 1.0 |
| Rainbow Municipal Water District | 2020s | warm-wet | 23.6 | 24.5 | 0.8 |
| Rainbow Municipal Water District | 2050s | hot-dry | 23.6 | 26.4 | 2.8 |
| Rainbow Municipal Water District | 2050s | hot-wet | 23.6 | 26.4 | 2.8 |
| Rainbow Municipal Water District | 2050s | middle | 23.6 | 25.8 | 2.2 |
| Rainbow Municipal Water District | 2050s | warm-dry | 23.6 | 25.2 | 1.5 |
| Rainbow Municipal Water District | 2050s | warm-wet | 23.6 | 24.9 | 1.3 |
| Ramona Municipal Water District | 2020s | hot-dry | 24.6 | 26.2 | 1.6 |
| Ramona Municipal Water District | 2020s | hot-wet | 24.6 | 26.2 | 1.6 |
| Ramona Municipal Water District | 2020s | middle | 24.6 | 25.9 | 1.2 |

| Agency | Period | Scenario | Max. Temperature (°C; Historical) | Max. Temperature (°C; Future) | Max. Temperature Change (°C) |
|---|---|---|---|---|---|
| Ramona Municipal Water District | 2020s | warm-dry | 24.6 | 25.6 | 1.0 |
| Ramona Municipal Water District | 2020s | warm-wet | 24.6 | 25.5 | 0.8 |
| Ramona Municipal Water District | 2050s | hot-dry | 24.6 | 27.5 | 2.8 |
| Ramona Municipal Water District | 2050s | hot-wet | 24.6 | 27.4 | 2.8 |
| Ramona Municipal Water District | 2050s | middle | 24.6 | 26.9 | 2.2 |
| Ramona Municipal Water District | 2050s | warm-dry | 24.6 | 26.2 | 1.6 |
| Ramona Municipal Water District | 2050s | warm-wet | 24.6 | 26.0 | 1.3 |
| Rincon Del Diablo Municipal Water District | 2020s | hot-dry | 24.0 | 25.6 | 1.6 |
| Rincon Del Diablo Municipal Water District | 2020s | hot-wet | 24.0 | 25.5 | 1.5 |
| Rincon Del Diablo Municipal Water District | 2020s | middle | 24.0 | 25.2 | 1.2 |
| Rincon Del Diablo Municipal Water District | 2020s | warm-dry | 24.0 | 24.9 | 0.9 |
| Rincon Del Diablo Municipal Water District | 2020s | warm-wet | 24.0 | 24.8 | 0.8 |
| Rincon Del Diablo Municipal Water District | 2050s | hot-dry | 24.0 | 26.8 | 2.8 |
| Rincon Del Diablo Municipal Water District | 2050s | hot-wet | 24.0 | 26.8 | 2.8 |
| Rincon Del Diablo Municipal Water District | 2050s | middle | 24.0 | 26.2 | 2.2 |
| Rincon Del Diablo Municipal Water District | 2050s | warm-dry | 24.0 | 25.5 | 1.5 |
| Rincon Del Diablo Municipal Water District | 2050s | warm-wet | 24.0 | 25.3 | 1.3 |
| San Dieguito Water District | 2020s | hot-dry | 24.1 | 25.6 | 1.5 |
| San Dieguito Water District | 2020s | hot-wet | 24.1 | 25.6 | 1.5 |
| San Dieguito Water District | 2020s | middle | 24.1 | 25.2 | 1.2 |
| San Dieguito Water District | 2020s | warm-dry | 24.1 | 25.0 | 0.9 |
| San Dieguito Water District | 2020s | warm-wet | 24.1 | 24.9 | 0.8 |

| Agency | Period | Scenario | Max. Temperature (°C; Historical) | Max. Temperature (°C; Future) | Max. Temperature Change (°C) |
|---|---|---|---|---|---|
| San Dieguito Water District | 2050s | hot-dry | 24.1 | 26.7 | 2.7 |
| San Dieguito Water District | 2050s | hot-wet | 24.1 | 26.8 | 2.7 |
| San Dieguito Water District | 2050s | middle | 24.1 | 26.2 | 2.1 |
| San Dieguito Water District | 2050s | warm-dry | 24.1 | 25.5 | 1.5 |
| San Dieguito Water District | 2050s | warm-wet | 24.1 | 25.3 | 1.3 |
| Santa Fe Irrigation District | 2020s | hot-dry | 24.5 | 26.1 | 1.5 |
| Santa Fe Irrigation District | 2020s | hot-wet | 24.5 | 26.0 | 1.5 |
| Santa Fe Irrigation District | 2020s | middle | 24.5 | 25.7 | 1.2 |
| Santa Fe Irrigation District | 2020s | warm-dry | 24.5 | 25.4 | 0.9 |
| Santa Fe Irrigation District | 2020s | warm-wet | 24.5 | 25.3 | 0.8 |
| Santa Fe Irrigation District | 2050s | hot-dry | 24.5 | 27.3 | 2.7 |
| Santa Fe Irrigation District | 2050s | hot-wet | 24.5 | 27.3 | 2.7 |
| Santa Fe Irrigation District | 2050s | middle | 24.5 | 26.7 | 2.1 |
| Santa Fe Irrigation District | 2050s | warm-dry | 24.5 | 26.0 | 1.5 |
| Santa Fe Irrigation District | 2050s | warm-wet | 24.5 | 25.8 | 1.3 |
| South Bay Irrigation | 2020s | hot-dry | 21.6 | 23.0 | 1.4 |
| South Bay Irrigation | 2020s | hot-wet | 21.6 | 23.0 | 1.5 |
| South Bay Irrigation | 2020s | middle | 21.6 | 22.7 | 1.1 |
| South Bay Irrigation | 2020s | warm-dry | 21.6 | 22.4 | 0.9 |
| South Bay Irrigation | 2020s | warm-wet | 21.6 | 22.4 | 0.8 |
| South Bay Irrigation | 2050s | hot-dry | 21.6 | 24.2 | 2.6 |
| South Bay Irrigation | 2050s | hot-wet | 21.6 | 24.2 | 2.6 |

| Agency | Period | Scenario | Max. Temperature (°C; Historical) | Max. Temperature (°C; Future) | Max. Temperature Change (°C) |
|---|---|---|---|---|---|
| South Bay Irrigation | 2050s | middle | 21.6 | 23.6 | 2.0 |
| South Bay Irrigation | 2050s | warm-dry | 21.6 | 23.0 | 1.4 |
| South Bay Irrigation | 2050s | warm-wet | 21.6 | 22.8 | 1.2 |
| Valley Center Municipal Water District | 2020s | hot-dry | 23.4 | 25.0 | 1.5 |
| Valley Center Municipal Water District | 2020s | hot-wet | 23.4 | 25.0 | 1.5 |
| Valley Center Municipal Water District | 2020s | middle | 23.4 | 24.6 | 1.2 |
| Valley Center Municipal Water District | 2020s | warm-dry | 23.4 | 24.4 | 0.9 |
| Valley Center Municipal Water District | 2020s | warm-wet | 23.4 | 24.3 | 0.8 |
| Valley Center Municipal Water District | 2050s | hot-dry | 23.4 | 26.2 | 2.8 |
| Valley Center Municipal Water District | 2050s | hot-wet | 23.4 | 26.2 | 2.8 |
| Valley Center Municipal Water District | 2050s | middle | 23.4 | 25.6 | 2.2 |
| Valley Center Municipal Water District | 2050s | warm-dry | 23.4 | 25.0 | 1.5 |
| Valley Center Municipal Water District | 2050s | warm-wet | 23.4 | 24.7 | 1.3 |
| Vallecitos County Water District | 2020s | hot-dry | 24.8 | 26.4 | 1.6 |
| Vallecitos County Water District | 2020s | hot-wet | 24.8 | 26.3 | 1.6 |
| Vallecitos County Water District | 2020s | middle | 24.8 | 26.0 | 1.2 |
| Vallecitos County Water District | 2020s | warm-dry | 24.8 | 25.7 | 1.0 |
| Vallecitos County Water District | 2020s | warm-wet | 24.8 | 25.6 | 0.8 |
| Vallecitos County Water District | 2050s | hot-dry | 24.8 | 27.6 | 2.8 |
| Vallecitos County Water District | 2050s | hot-wet | 24.8 | 27.6 | 2.8 |
| Vallecitos County Water District | 2050s | middle | 24.8 | 27.0 | 2.2 |
| Vallecitos County Water District | 2050s | warm-dry | 24.8 | 26.3 | 1.6 |

| Agency | Period | Scenario | Max. Temperature (°C; Historical) | Max. Temperature (°C; Future) | Max. Temperature Change (°C) |
|---|---|---|---|---|---|
| Vallecitos County Water District | 2050s | warm-wet | 24.8 | 26.1 | 1.3 |
| Vista Irrigation District | 2020s | hot-dry | 22.6 | 24.2 | 1.6 |
| Vista Irrigation District | 2020s | hot-wet | 22.6 | 24.1 | 1.5 |
| Vista Irrigation District | 2020s | middle | 22.6 | 23.8 | 1.2 |
| Vista Irrigation District | 2020s | warm-dry | 22.6 | 23.6 | 0.9 |
| Vista Irrigation District | 2020s | warm-wet | 22.6 | 23.4 | 0.8 |
| Vista Irrigation District | 2050s | hot-dry | 22.6 | 25.4 | 2.8 |
| Vista Irrigation District | 2050s | hot-wet | 22.6 | 25.4 | 2.8 |
| Vista Irrigation District | 2050s | middle | 22.6 | 24.8 | 2.2 |
| Vista Irrigation District | 2050s | warm-dry | 22.6 | 24.1 | 1.5 |
| Vista Irrigation District | 2050s | warm-wet | 22.6 | 23.9 | 1.3 |
| Yuima Municipal Water District | 2020s | hot-dry | 24.1 | 25.7 | 1.6 |
| Yuima Municipal Water District | 2020s | hot-wet | 24.1 | 25.7 | 1.6 |
| Yuima Municipal Water District | 2020s | middle | 24.1 | 25.4 | 1.3 |
| Yuima Municipal Water District | 2020s | warm-dry | 24.1 | 25.1 | 1.0 |
| Yuima Municipal Water District | 2020s | warm-wet | 24.1 | 25.0 | 0.8 |
| Yuima Municipal Water District | 2050s | hot-dry | 24.1 | 27.0 | 2.9 |
| Yuima Municipal Water District | 2050s | hot-wet | 24.1 | 26.9 | 2.8 |
| Yuima Municipal Water District | 2050s | middle | 24.1 | 26.4 | 2.2 |
| Yuima Municipal Water District | 2050s | warm-dry | 24.1 | 25.7 | 1.6 |
| Yuima Municipal Water District | 2050s | warm-wet | 24.1 | 25.5 | 1.3 |