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14 CLIMATE CHANGE

14.1 INTRODUCTION

Consistent with California state guidelines for Integrated Regional Water Management (IRWM) planning, climate change analysis is considered a critical component in the planning and implementation of water resources management projects and programs. The IRWM Guidelines require that IRWM Plans address both adaptation to the effects of climate change and mitigation of greenhouse gas (GHG) emissions related to water systems. The IRWM Plan must also include discussion of the potential effects of climate change on the IRWM region and an assessment of the region's climate change vulnerabilities. Each IRWM Region is required develop a list of prioritized vulnerabilities and incorporate a consideration of regional climate change effects into the appropriate sections of their IRWM Plan.

The purpose of this section is to:

1. **Educate the reader on the contributing factors and measurements of climate change** – a brief introduction to define the terminology used in the section and how each contributes to the understanding of climate change
2. **Summarize how Climate Change Analysis is performed** – a discussion of the global models and downscaled data used in the analysis performed in the section's Climate Change Analysis
3. **Describe the Climate Change Analysis results** – a summary of the Climate Change Analysis results breaking down the differences between the three Sub-Regions of the SLO IRWM Region
4. **Present the results of the vulnerability assessment for the IRWM Region** – a synopsis of the vulnerability assessment, presentation of the prioritized list of vulnerabilities, and explanation of how vulnerabilities were evaluated
5. **Discuss how the SLO RWMG plans to address climate change** – a description of the RWMG's feasibility to address vulnerabilities and summary of how climate change considerations impact the IRWM Plan as a whole

The scientific study for this section is derived from **Appendix J – Climate Change Analysis for San Luis Obispo IRWM Region** and various climate change related websites referred to in the appendix and in this section.

14.1.1 IRWM Plan Climate Change Outline

While this section includes a comprehensive depiction of how climate change is addressed by the IRWM Plan, climate change considerations are weaved into various other sections of the Plan. **Table 14-1** below lists the other sections of the Plan in which climate change is addressed and an overview of the climate change-related information contained in those sections.

Table 14-1: IRWM Plan Climate Change Outline

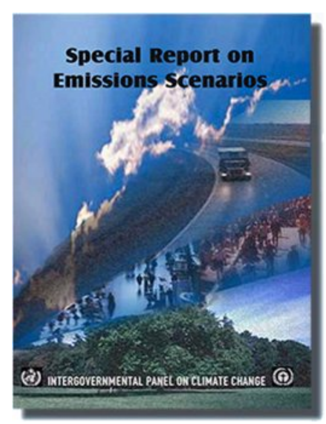
Section	Summary
Section 3.13	An overview of the regional, anticipated climate change effects is supplemented by thorough descriptions of the climate change effects expected within each sub-region.
Section 4.3.1	This subsection describes how the Plan Objectives were reviewed to ensure they adequately reflect the region's top prioritized climate change vulnerabilities and incorporate climate change adaptation and mitigation strategies.
Section 5.2.3	A brief summary of how the Plan's RMS have been evaluated to ensure they encompass adaptation and mitigation strategies.
Section 6	The project evaluation criteria include a consideration of how proposed projects address the region's prioritized climate change vulnerability and incorporate strategies for climate change adaptation and mitigation.
Section 9.4.3	The RWMG anticipates new information and tools related to climate change to arise in the future, and this Section includes a summary of the RWMG's plan for incorporating such developments into the IRWM Plan.

14.2 Climate Change Projections

Climate change is often described as a significant and lasting change in the weather patterns over extended periods of time ranging from decades to millions of years.

14.2.1 Emissions Scenarios

Emission scenarios are alternative "storylines" of how the future might unfold based on driving forces such as population growth, land use change, technology, and industry and how those forces influence future emissions of GHG. The storylines help define future concentrations of GHG in the atmosphere and how GHG impacts temperature and climate. Unfortunately, as with any forecast modeling, the possibility that any single emissions path will occur as described by the scenarios is highly uncertain, so multiple scenarios with differing characteristics have been developed.



In the early 1990s, the Intergovernmental Panel on Climate Change (IPCC) developed long-term emissions scenarios that have been widely used in the analysis of climate change and its impacts. In 1996, the IPCC made the decision to update the emission scenarios to account for the carbon intensity of the world's energy supply, to represent the significance of the income gap between developed and developing countries, and to include sulfur emissions as a climate changing variable. In 2000, the emission scenarios were updated again to identify regions acknowledging agreement in the direction of future climate change as well as regions where projected changes were thought to be more uncertain. Information on the statistical significance of projected changes in relation to modeled natural climate variability was included.

The IPCC's Special Report on Emissions Scenarios (SRES) includes four primary storylines of how the world may move forward with corresponding changes in climate. The preferred storyline and scenario family utilized for this analysis is the A1 storyline. In contrast to the use of the A2 storyline by a 2010 study on future conditions in San Luis Obispo County, this decision reflects a more optimistic growth scenario for the economy and a world which brings to bear technological solutions to reduce GHG emissions starting mid-Century (2050).

Figure 14-1 is from IPCC's Third Assessment Report, and it illustrates the differences in future emissions and related conditions between six scenarios derived from the IPCC's four storylines. Plots are briefly described as follows: (a) the CO2 emissions of the six SRES scenarios; (b) projected CO2 concentrations; (c) anthropogenic SO2 emissions; (d) the projected temperature change; (e) sea-level rise projections.

Focusing on the (a) plot and following the A1B line (solid red line), the trace shows a relatively steep increase in carbon emissions in the first half the century to the mid-century mark (2050) and then a slow gradual decrease to 2100. Intuitively, this reflects the continued use of carbon fuels until green energy technology has evolved and is brought to bear on reducing the rate of emissions. However, the A1B temperature trace shown in the (d) plot is similar to all emission scenarios and continues to rise until the end of the century. As illustrated in **Figure 14-2**, the A1B scenario is a balance between the more fossil fuel intensive scenario (A1F) and the non-fossil/green-energy scenario (A1T). The A1B scenario is selected for this analysis to represent the "most-likely" set of conditions for the IRWM Region looking out to 2100.

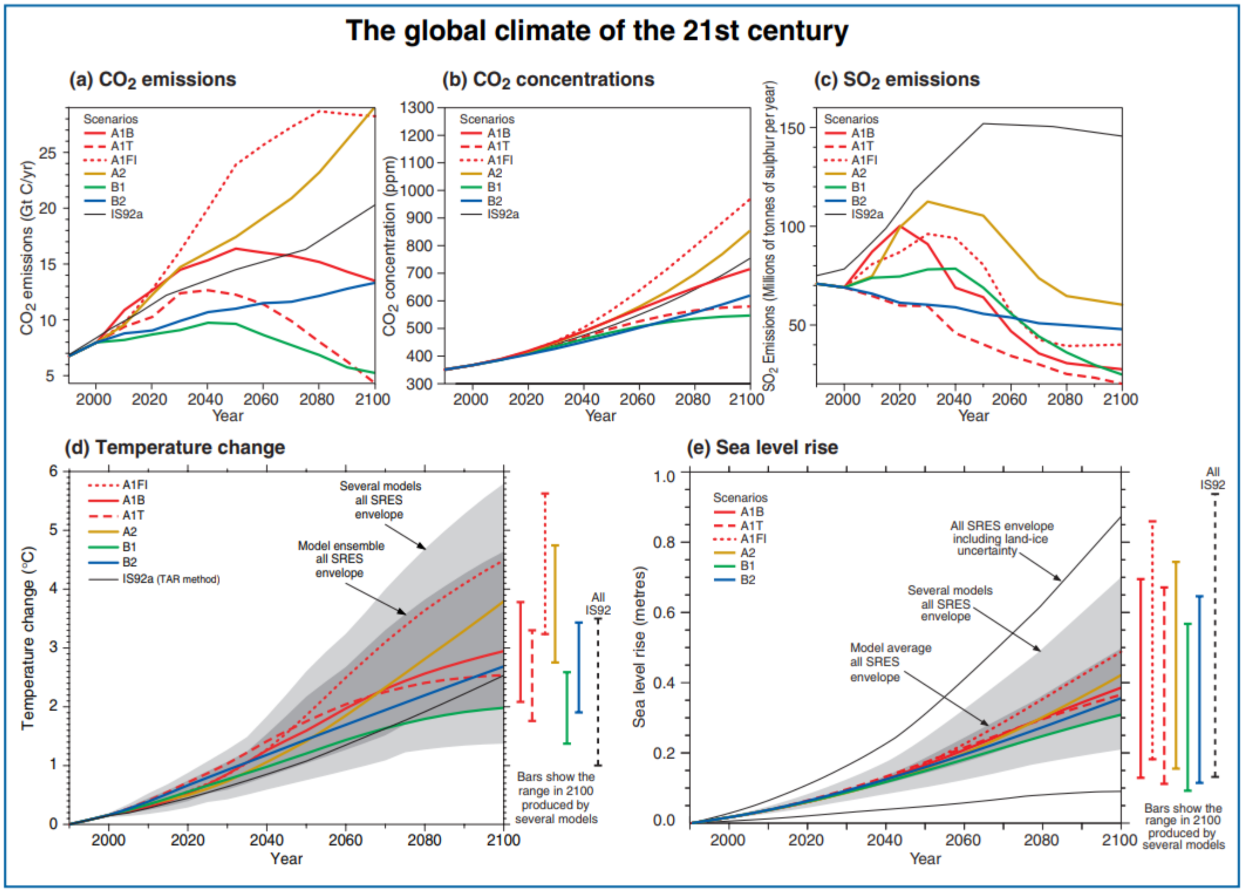


Figure 14-1: *Results of SRES Climate Change Scenarios*

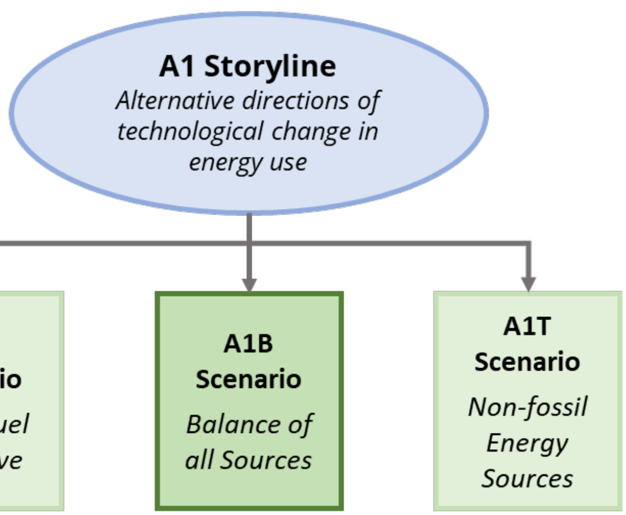


Figure 14-2: *A1 Storyline Scenarios*

14.3 Climate Change Models

Downscaling of global data is important for a study looking at the effects of climate change in a relatively small geographical area. Downscaling of global model results from the IPCC SRES scenarios refers to a process of taking the global model data on forecasted changes to climate variables (e.g., temperature and precipitation), and translating it to a finer spatial scale that is more meaningful in the context of local and regional impacts.

14.3.1 Selected Model for Climate Change Analysis

Significant research and consideration was employed to select the appropriate climate change models for the SLO IRWM Climate Change Analysis. The decision to use NOAA Geophysical Fluid Dynamics Laboratory (GFDL) models for the climate change analysis is based on the following:

- Downscaled data from the model is available at a resolution to differentiate between the potential impacts in the three Sub-Regions covered in the IRWM Plan
- Daily downscaled data is available for all emission scenarios to facilitate computing change in indices related to energy and water use
- The NOAA models and approach had been utilized in three other region-developed IRWM Plans at the time of development (Imperial Region, Gateway Region, San Joaquin Region)

14.3.2 Applying Global Models to SLO IRWM Region

For the SLO IRWM Region, the downscaled global datasets need to be applicable to the three Sub-Regions defined in the IRWM Plan. The Lawrence Livermore National Labs (LLNL) hosts an archive of the results of global climate projections from the World Climate Research Program's Coupled Model Intercomparison Project (CIMP) Phase 3 effort and offers statistically-downscaled data for use in modeling smaller regions. The downscaling includes bias-corrected data to better match the magnitude of modeled precipitation and temperature to observed values in the local region. As described above, simulations from NOAA's GFDL models run for the A1B emissions scenario were used for the 2014 IRWM Plan Update Climate Change Analysis. The data grid over which the data request was made is illustrated in **Figure 14-3** with the Sub-Region areas shaded to illustrate the resolution of coverage. By splitting the IRWM Region into its three Sub-Regions, the analysis afforded more detail than prior efforts to understand climate change impacts. This results of this analysis, summarized in subsequent sections, provided a foundation for the prioritization of regional vulnerabilities (**Section 14.8**) and future data gathering and analysis.

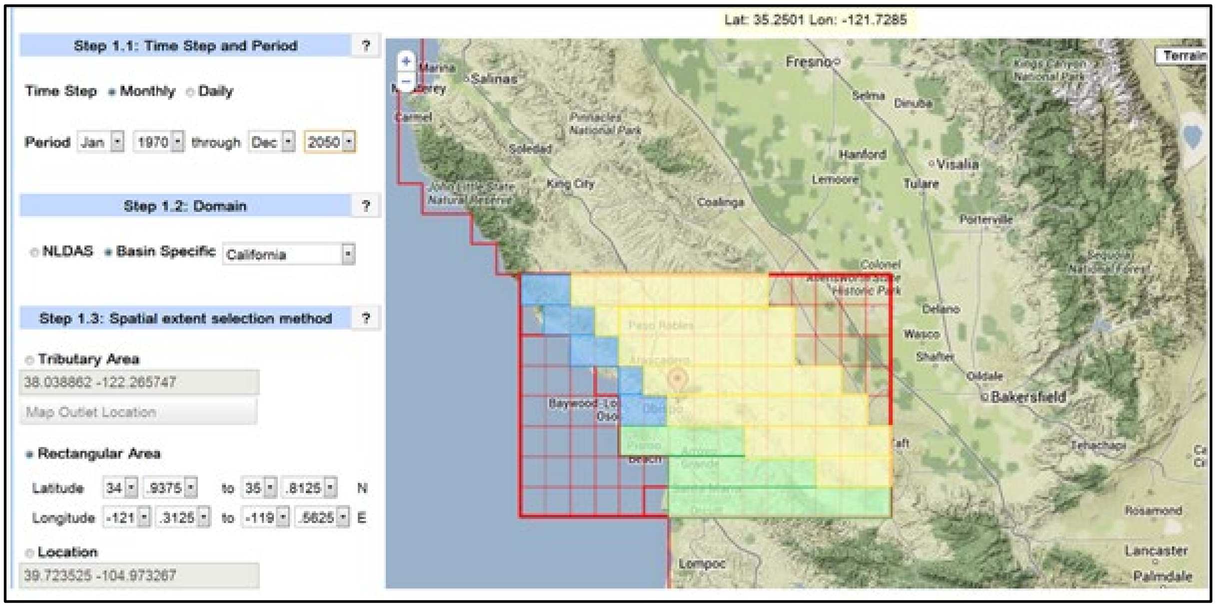


Figure 14-3: *Downscaled Region Model Grid Data Request for IRWM Region*

14.4 Approach to Climate Change Analysis for Sub-Regions

Climate Change Analysis for the three Sub-Regions in the IRWM Plan required sufficient time series data, both in resolution and in temporal span. The analysis required monthly and daily time series data to characterize climate in the recent past (prior to 2011) and at mid-century (2050), approximately 30 years into the future. The use of mid-century as a future date ensured full coverage of the 20- to 25-year IRWM Planning horizon.

14.4.1 Metrics for Measuring Climate Change

Changes between historical and future global simulation results are summarized in terms of monthly and seasonal differences for precipitation, maximum temperature, minimum temperature, wind speed, evapotranspiration, and runoff. These changes were obtained by analyzing the monthly simulated data. Daily time series data was used to calculate the average seasonal change in growing degree days, heating degree days, cooling degree days, and days with precipitation of more than 1 inch. Both metric categories (i.e., monthly and seasonal) are used to quantitatively express changes in the climate parameters and are described below.

14.4.2 Monthly Time Series Metrics

Precipitation – Average monthly rainfall amounts (inches and mm)

Maximum Temperature – Average monthly maximum daily temperatures °F (°C)

Minimum Temperature – Average monthly minimum daily temperatures °F (°C)

Wind Speed – Average monthly wind speed (m/s)

Evapotranspiration – Average monthly evapotranspiration rates (mm)

Runoff – Estimate average monthly runoff from rainfall (mm/month)

14.4.3 Daily Time Series Metrics

Growing Degree Days

Growing Degree Days (GDD) are associated with the regional climate and its ability to provide the optimal range in temperature for growing crops. While optimal growing conditions differ for each crop, growing conditions for all crops typically range between 46°F (8°C) for low growth and 90°F (32°C) for high growth.

On any given day of the year, if the daily mean temperature falls within this range (see figure below), the day is counted as a growing day and is weighted by how close the temperature falls to the high growth temperature.

Heating Degree Days

Days with a mean daily temperature below 65°F (18°C), the minimum base temperature, are considered to be Heating Degree Days (HDD) below which buildings need to be heated.

Cooling Degree Days

Cooling Degree Days (CDD) occur when daily mean temperatures are above 75°F (24°C), the maximum base temperature, and buildings require air conditioning to cool temperatures.

14.4.4 Conceptual Model Setup and Analysis

The analysis flow diagram shown in **Figure 14-4** is illustrative of the processes and interactions taking place in the modeling of climate change. As shown in the figure, economic systems are the foundational stressors towards positive and negative changes in climate. The chosen model scenario (A1B) is closely defined by what the world economy may look like and what the human society will do about the changes taking place, both environmental and anthropogenic. The diagram indicates the feedback between each of the processes illustrating how with each time step a new equilibrium is reached producing a new set of climate conditions.

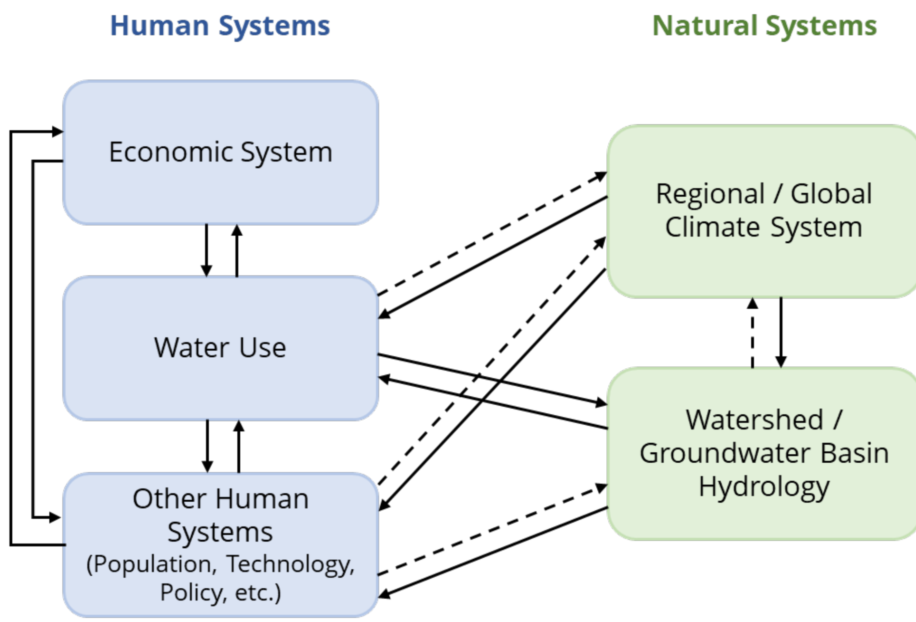


Figure 14-4: *Analysis Flow Diagram*

Since the Climate Change Analysis was performed on a sub-regional scale, it is important to recognize the socio-economic conditions and other influential elements that characterize each of the Sub-Region. A general summary of the important distinguishing factors of each Sub-Region is provided in **Table 14-2**.

Urbanized land uses in the IRWM region exist in various degrees within each of the three Sub-Regions. However, it is widely known that most, if not all, urban areas continuously struggle with water supply, drainage, transportation, and environmental challenges regardless of their relative size, location, and local hydrology. Due to these similarities, the resulting impacts of climate change in urban areas are not considered to be significantly different between the three Sub-Regions and are not reflected in **Table 14-2**.

Table 14-2: Socio-Economic and Water Resources Considerations by Sub-Region

North Coast Sub-Region	• Sea-level rise along the coastline can significantly impact low-lying areas and groundwater supplies (often the primary source of drinking water) by saltwater intrusion • Small aquifers offer low aquifer storage capacity • Timing of rainfall and runoff is critical to recharging the region's smaller groundwater basins where groundwater storage is constrained by aquifer size and salt water intrusion (i.e., changes in rainfall patterns can cause a possible loss of natural recharge) • Local economies of communities (e.g., fishery and harbor industries), are reliant on coastal tourism requiring protection of ecosystems and infrastructure • Seawater intrusion and impacts of climate change and sea-level rise could impact Morro Bay National Estuary, a federally protected marine area with a variety of species, and other ecological preserve areas • California State Route Highway 1 coastal transportation route from approximately Carmel to the north, to San Simeon is sensitive to changing weather patterns causing slides and long-term road closures, shutting off north-bound and south-bound lanes for weeks, impacting primarily tourism
North County Sub-Region	• A larger wine and vineyard-based economy in the Paso Robles Groundwater Basin is sensitive to changing amounts of rainfall, and temperatures governing growing days and sensitive harvest periods • Agricultural water demands also have the potential to change (up or down) as a result of the need to change cropping patterns or cropping cycles to accommodate rainfall patterns • Local economies of communities (such as lake recreation and agricultural-related industries) are reliant on tourism requiring the ability to sustain the attractions and natural resources • Changes in the flow patterns of the Salinas River dictate the amount of irrigation water and natural recharge to the Paso Robles Groundwater Basin on an annual basis • The region contains critical ecosystems, such as 180,000-acre Carrizo Plain, one of the largest intact California grasslands, home to more endangered species than anywhere else in California, and home to Soda Lake, a sensitive ecosystem • State Water Project water is potentially available to increase imported surface water; however, these supplies are projected to have lower reliability with the potential for stressing local and regional groundwater resources and exacerbating salinity intrusion

Table 14-2: Socio-Economic and Water Resources Considerations by Sub-Region, Continued

South County Sub-Region	• A larger agricultural economy in the Santa Maria Groundwater Basin is sensitive to changing amounts of natural groundwater recharge and temperatures governing growing days • Agricultural water demands also have the potential to change (up or down) as a result of the need to change cropping patterns or cropping cycles to accommodate rainfall patterns • Local coastal economies of communities sustained by recreation and tourism-related industries are reliant on maintaining the attractive natural resources of beaches, estuaries, and woodlands • California State Water Project water contracts are available and being used to increase imported surface water; however, these supplies are projected to have lower reliability with the potential for stressing local and regional groundwater resources and exacerbating salinity intrusion • Seawater intrusion, sea-level rise, and impacts of climate change could impact the Guadalupe-Nipomo Dunes Wetland (and oil field), the largest coastal dune ecosystem in the Western U.S. with a variety of species, and other ecological preserve areas • Sea-level rise can significantly impact the coastal low lying urban areas at risk of flooding from the Arroyo Grande, Pismo Creek, and Meadow Creek watersheds; especially, during periods of coincident high tide and flooding resulting from increased rain storm intensity • Diablo Canyon Nuclear Power Plant uses seawater for cooling and can be impacted through coastal storms, flooding, and sea-level rise

14.5 Climate Change Analysis Results

The Climate Change Analysis is the execution of the model assuming the mid-century (2050) carbon production conditions of the A1B Scenario shown in **Table 14-3,** and running those conditions through 40 years of monthly hydrology and 20 years of daily hydrology develop a statistical average of the various climate variables. In this way, the model results are presented so the mid-century results of climate variables are representative of an average over a hydrologic period of record to account for the naturally occurring dry- and wet-period hydrology.

Table 14-3 below provides results of the Climate Change Analysis using monthly data aggregated to seasonal time periods for the mid-century point in time. The table and figures below illustrate the change in average seasonal amounts for key climate variables.

Table 14-3: *Projected Changes in Monthly Climate Metrics by Mid-Century (2050)*

Variable	Sub-Region	Change in Variables Projected for Medium Warming Scenario (A1B)				
		Winter	Spring	Summer	Fall	Annual
Precipitation	North Coast	7.2%	-26.2%	-38.5%	3.2%	-3.66%
	South County	7.0%	-27.5%	-32.5%	0.9%	-5.02%
	North County	6.9%	-27.2%	-41.0%	-1.4%	-5.15%
Maximum Temperature	North Coast	6.5%	4.2%	5.8%	5.6%	5.48%
	South County	6.6%	4.6%	6.1%	6.0%	5.81%
	North County	7.5%	4.5%	5.0%	5.9%	5.55%
Minimum Temperature	North Coast	18.8%	13.5%	9.8%	17.0%	13.91%
	South County	23.2%	14.1%	11.2%	18.8%	15.40%
	North County	49.9%	15.4%	12.1%	21.8%	17.76%
Wind Speed	North Coast	-0.1%	-1.8%	0.2%	1.2%	-0.25%
	South County	0.2%	-1.2%	-0.8%	0.7%	-0.32%
	North County	0.3%	-1.0%	-0.6%	0.8%	-0.21%
Evapotranspiration	North Coast	-3.6%	3.9%	7.0%	6.1%	4.79%
	South County	-1.8%	3.8%	7.1%	6.0%	4.90%
	North County	-4.0%	4.6%	6.2%	5.2%	4.37%
Runoff	North Coast	15.7%	-27.8%	-3.3%	-1.4%	-3.47%
	South County	12.8%	-33.7%	-4.4%	1.7%	-8.78%
	North County	16.2%	-27.8%	-3.2%	-0.5%	-3.70%

In the table above, the cells with green backgrounds indicate increases of 3 percent or more change from current seasonal average; red backgrounds indicate decreases of 3 percent or more; and white backgrounds indicate no significant change. The table values provide a sense of the order of magnitude of change projected in 2050 as a result of climate change assuming the A1B Scenario conditions of carbon productions. Each of these key climate variables and the effects of climate change on the Sub-Regions are described below.

14.5.1 Precipitation Changes

Precipitation is a key indicator of climate change. Both when (temporal) and how much (volume) rainfall occurs have a significant impact to the region's infrastructure and river systems in their capacity to convey flood waters and naturally recharge freshwater aquifers, respectively. The percent changes shown in the table above express that in the future there will be more rainfall in the winter and less rainfall in the spring. It should be noted, the order of magnitude in the change seen in spring stems from the small amount of rainfall that occurs during the spring months of the year. The approximate 0.4-inch seasonal average decrease in rainfall over the North County Sub-Region area in spring produces a 27 percent decrease from the current seasonal average of 1.6 inches. Whereas, a 0.5-inch increase over the same area in winter, with a current 6-inch average rainfall, produces a 6.9 percent increase.

Precipitation drives many of the interactions taking place in the **Figure 14-4** analysis flow diagram**.** It is important to quantify the shift in rainfall from month to month, as demonstrated in **Figure 14-5** below**.** The graph shows a monthly average precipitation difference comparison of the three Sub-Regions. As a whole, the graph indicates most of the change is taking place in the North Coast Sub-Region with a reduction in precipitation change as one moves inland from the ocean.

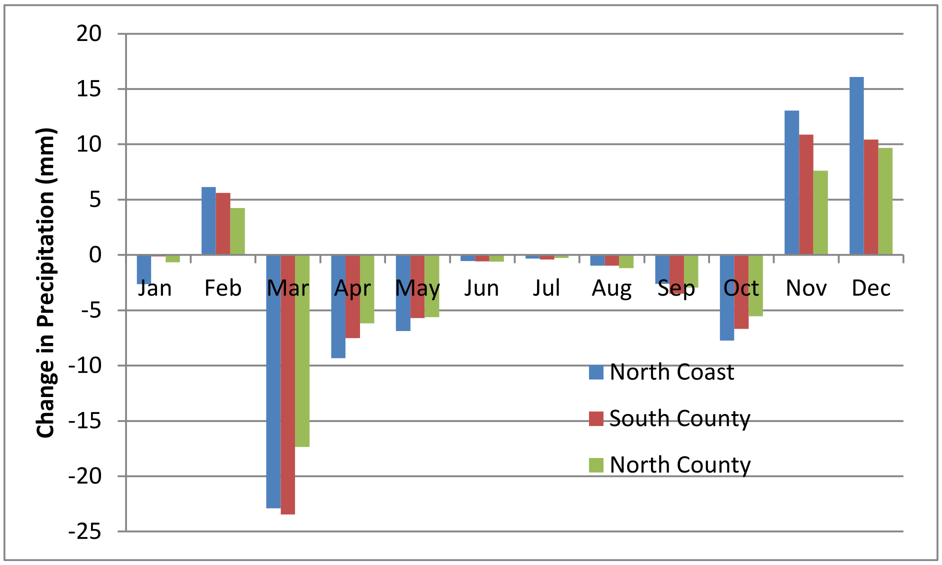


Figure 14-5: *Differences in Average Monthly Precipitation*

14.5.2 Temperature Changes

Temperature drives how much water is needed to satisfy both human and natural water demands, and a shift in temperature can reduce or increase this need for water over the months of the year. An increase in temperature raises the amount of evapotranspiration from agricultural production and outdoor landscaping which, in turn, necessitates the application of additional irrigation water.

Figure 14-6 and **Figure 14-7** provide the differences in maximum and minimum daily temperatures. A rise in maximum temperatures indicates hotter day time temperatures and a rise in minimum temperatures indicate hotter night time temperatures (when compared with existing conditions). The two graphs indicate that the entire region will see an increase in temperature year-round. The South County Sub-Region extends further inland than the North Coast Sub-Region and so has similar characteristics to the North County Sub-Region in terms of temperature change in some months of the year. The greatest absolute and comparative difference between the Sub-Regions occurs during the summer months.

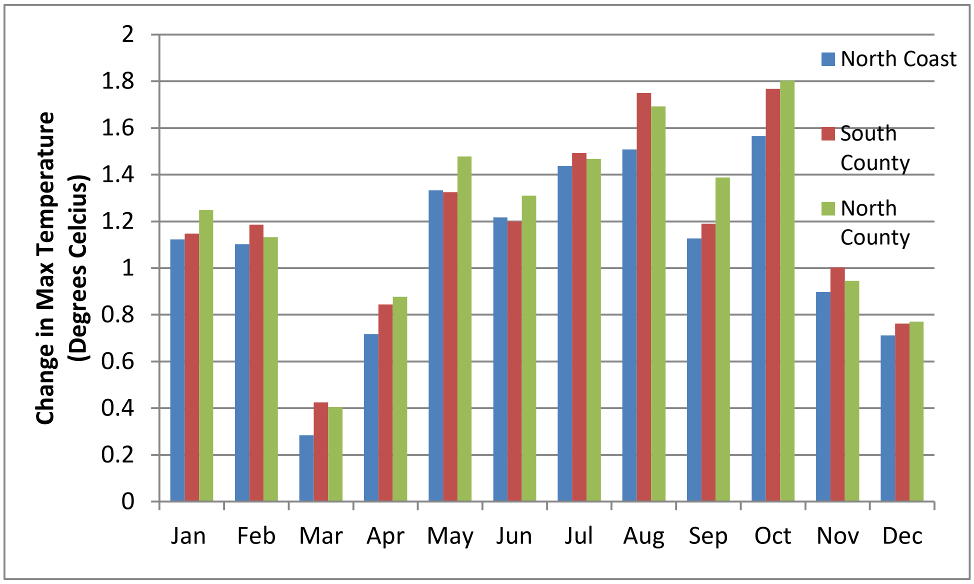


Figure 14-6: *Differences in Average Monthly Maximum Temperatures*

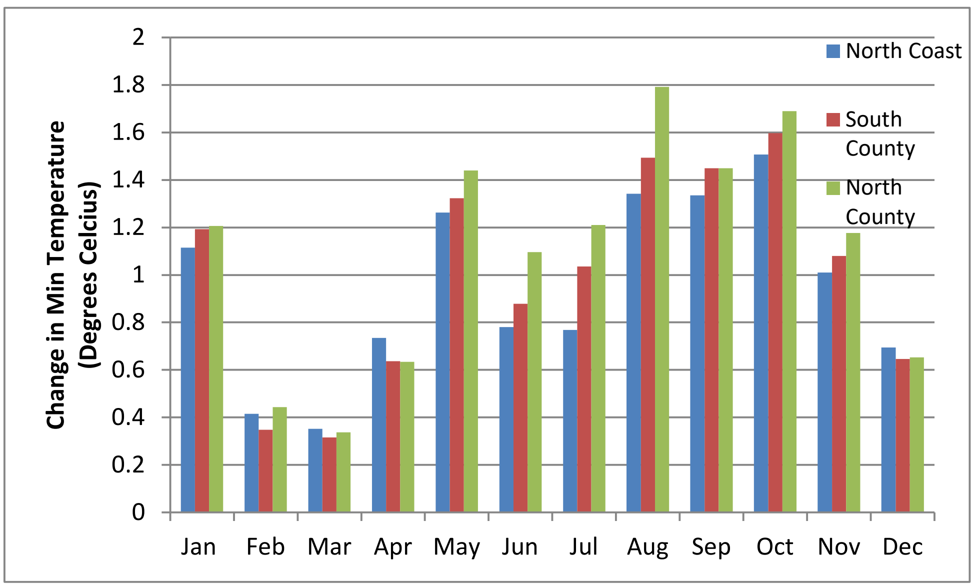


Figure 14-7: *Differences in Average Monthly Minimum Temperatures*

14.5.3 Evapotranspiration Changes

Evapotranspiration (ET) is a measure of how the Sun's radiation affects the amount of water needed by plants to sustain growth. **Figure 14-8** provides a comparison of the ET changes amongst all three Sub-Regions. The graph shows relatively little difference between the three Sub-Regions and highlights how ET is projected to significantly increase across the region during summer months. The North County Sub-Region, with its strong agricultural community, anticipates increased ET during the spring growing season. These changes will heighten agriculture water demands and add stress to several already vulnerable water supplies.

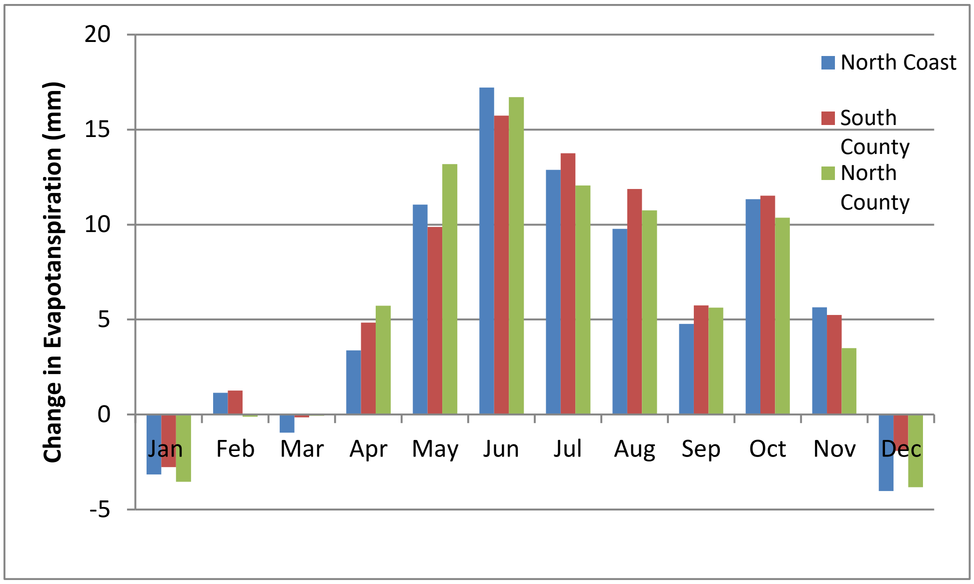


Figure 14-8: *Differences in Monthly Evapotranspiration*

14.5.4 Runoff Changes

Runoff is a measure of how much rainfall hits the ground and does not infiltrate or percolate to replenish groundwater supplies. This is an indicator of the intensity of storms, the size of the aquifers, and the soil moisture conditions. When rainfall events are spaced out and of low intensity, the region has an improved chance of capturing the water through deep percolation to groundwater supplies (or possibly to fractured rock). When soil moisture conditions reject the water, or aquifers become full, runoff occurs and is routed to streams, rivers, reservoirs, and the ocean. Changes in the intensity and frequency of rainfall events and resulting changes in runoff can significantly impact a reservoir's operations and lead to insufficient stored water during peak water demands. **Figure 14-9** indicates the North Coast Sub-Region will experience the highest monthly change in runoff, with reduced change toward the inland regions. This response is in part due to smaller watersheds and small capacity aquifers along the North Coast, which create shorter response times and make the area more sensitive to changes in storm event patterns.

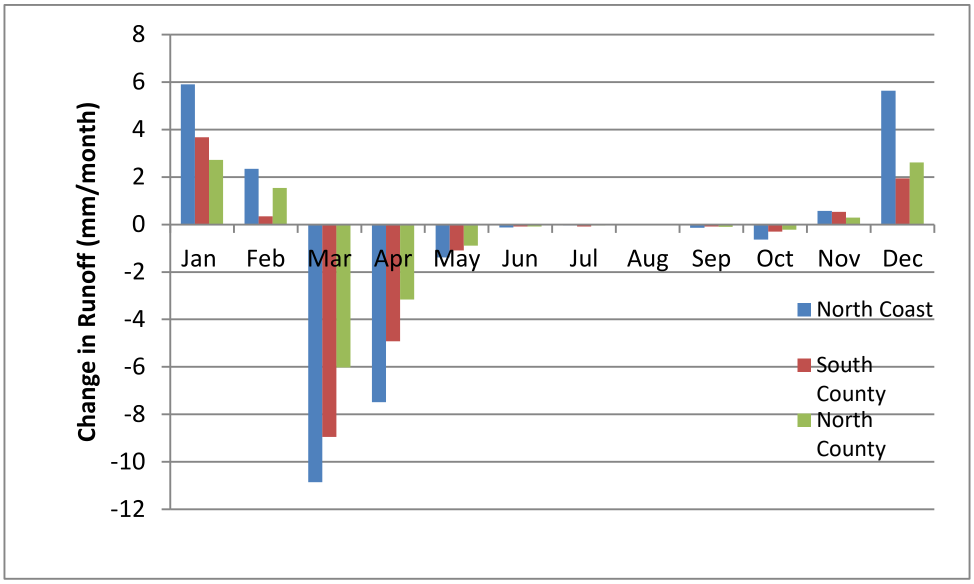


Figure 14-9: *Differences in Average Monthly Runoff*

14.5.5 Daily Climate Change Results Expressed as Degree Days and Precipitation

With daily simulation data, the resolution of change significantly increases when considering how much warmer or cooler the temperatures will be, on average, for any given day of the year. **Section 14.4.3** defines the concept of degree days, a metric of change that relates to the use of water and energy to its impact on the economy. **Table 14-4** below summarizes the projected changes in the climate's daily metrics by mid-century with increases shown in green background and decreases shown in red backgrounds. Cells with white backgrounds indicate no significant change.

Table 14-4: *Projected Changes in Daily Climate Metrics by Mid-Century (2050)*

Variable	Sub-Region	Change in Variables Projected for Medium Emissions (A1B)			
		Winter	Spring	Summer	Fall
Growing Degree Days	North Coast	148.84	239.77	435.81	303.29
	South County	150.04	240.46	423.37	283.37
	North County	147.33	249.11	363.65	283.60
Heating Degree Days	North Coast	-288.00	-337.35	-214.49	-279.32
	South County	-296.08	-338.93	-190.82	-264.11
	North County	-306.75	-311.36	-48.87	-244.22
Cooling Degree Days	North Coast	0.00	0.00	1.16	0.37
	South County	0.00	0.05	1.51	0.41
	North County	0.00	0.69	80.83	10.44

14.5.6 Changes in Growing Degree Days

The change in GDDs occurring in the North County Sub-Region is a good illustration of the utility of GDDs as a metric. Using vineyards as a surrogate for agricultural crops in the SLO Region, the number of GDDs increases with an increase in temperature.

The difference in the number of summer GDDs for the two coastal Sub-Regions appears to be slightly higher. This is caused by two factors: higher minimum temperatures due to temperate ocean influence along the coastline, and a lower number of GDDs currently along the coast than in the North County Sub-Region.

Figure 14-10 shows plots of both the projected and past average daily temperatures and has been used to illustrate the shift in GDDs. The graph shows the temperature shift is reducing the total number of days with an average temperature of less than 46 °F (8°C) by a total of 33 days (see cross-hatched area representing days no longer less than minimum temperature). Since these 33 days will all have an average temperature greater than the minimum temperature needed for plant growth (8 °C) and no days will have an average temperature exceeding the maximum temperature for plant growth (32 °C), the total number of growing days increases for the year.

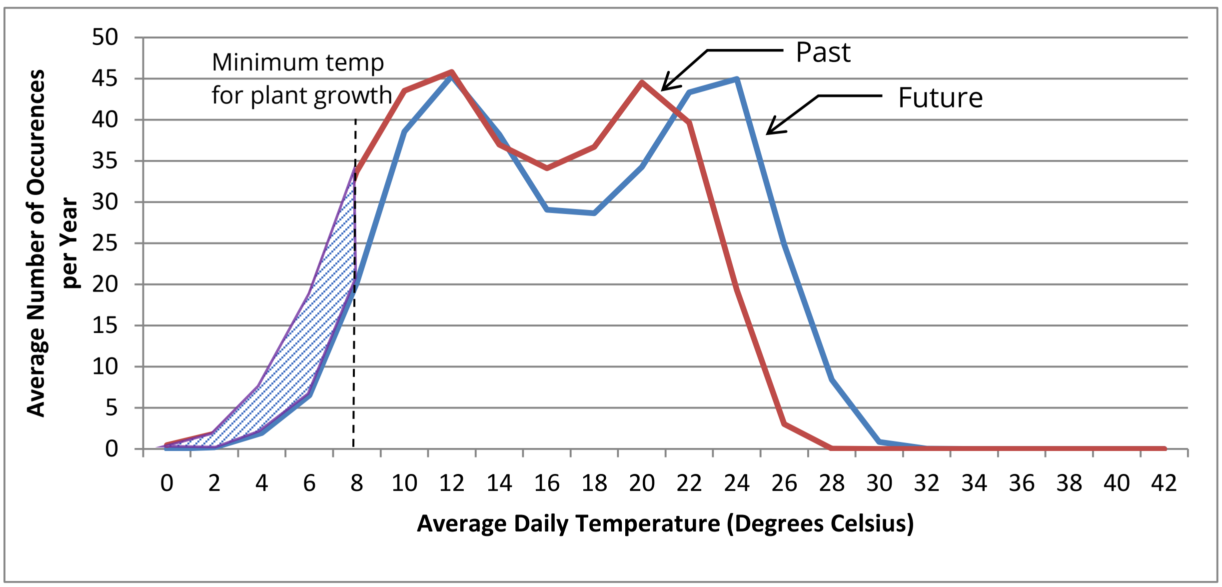


Figure 14-10: *Plot of Average Daily Temperatures*

14.5.7 Overall Sub-Region Findings for Climate Change Analysis

Table 14-5 provides additional details and general findings substantiating the results presented above for each Sub-Region.

Table 14-5: Summary of Climate Change Findings as Related to Changes in Regional Water Resources

Climate Variables	North Coast Sub-Region	North County Sub-Region	South County Sub-Region
Rainfall	Increase in winter precipitation up to 7% and decreases in dry season precipitation up to 38% indicate a shift in precipitation cycles, with an overall decrease in annual precipitation up to 4%	Increase in winter precipitation up to 7% and decreases in dry season precipitation up to 41% indicate shift in precipitation cycles, with an overall decrease in annual precipitation up to 5%	Increase in winter precipitation up to 7% and decreases in dry season precipitation up to 32% indicate shift in precipitation cycles, with an overall decrease in annual precipitation up to 5%
Maximum Temperature	Increases by 4.2% - 6.5% in maximum temperatures throughout the year (in degree Celsius) indicate an overall increase in warming patterns	Increases by 4.5% - 7.5% in maximum temperatures throughout the year (in degree Celsius) indicate an overall increase in warming patterns	Increases by 4.6% - 6.6% in maximum temperatures throughout the year (in degree Celsius) indicate an overall increase in warming patterns
Minimum Temperature	Increases by 9.8% - 18.8% in minimum temperatures throughout the year (in degree Celsius) indicate warmer night time temperatures	Increases by 12.1% - 49.9% in minimum temperatures throughout the year (in degree Celsius) indicate warmer night time temperatures. This region has below freezing winter temperatures, hence the changed values are sensitive to small changes in temperatures	Increases by 11.2% - 23.2% in minimum temperatures throughout the year (in degree Celsius) indicate warmer night time temperatures
Wind Speed	Minor changes in wind speeds ranging from increases up to 1% and decreases up to 2% possibly affecting evapotranspiration	Only minor changes in wind speeds ranging from increases of less than 1% and decreases up to 1%	Only minor changes in wind speeds ranging from increases of less than 1% and decreases up to 1%
Evapo-transpiration	Increases up to 7% expected in evapotranspiration in all seasons except winter where a decrease up to 3% indicate the need for a shift in irrigation patterns	Increases up to 6% expected in evapotranspiration in all seasons except winter where a decrease up to 4% indicate the need for a potential shift in irrigation patterns	Increases up to 7% expected in evapotranspiration in all seasons except winter where a decrease up to 2% indicate the need shift in irrigation patterns
Runoff	Increases in runoff in the winter by 15.7% and decreased runoff in the dry seasons up to 27.8% indicate shift in runoff patterns	Increases in runoff in the winter by 16.2% and decreases in runoff in the dry seasons up to 27.8% indicate shift in runoff pattern	Increases in runoff in the winter by 12.8% and decreased runoff in the dry seasons up to 33.7% indicate shift in runoff patterns
Heating/Cooling Degree Days	Significant decreases in heating requirements (heating degree days) through all the seasons due to higher	Significant decreases in heating requirements (heating degree days) through all the seasons due to higher	Significant decreases in heating requirements (heating degree days) through all the seasons due to higher

Climate Variables	North Coast Sub-Region	North County Sub-Region	South County Sub-Region
	temperatures and minor increases in cooling requirements (cooling degree days) in summer and fall indicate higher energy costs in cooling building	temperatures and minor increases in cooling requirements (cooling degree days) in spring, summer and fall indicate higher energy costs in cooling buildings	temperatures and minor increases in cooling requirements (cooling degree days) in spring, summer and fall indicate higher energy cost in cooling buildings
Growing Degree Days	Increases in ambient growing temperatures (growing degree days) for plants in all seasons indicate need to alter crop types and water requirements	Increases in ambient growing temperatures (growing degree days) for plants in all seasons indicate need to alter crop types and water requirements	Increases in ambient growing temperatures (growing degree days) for plants in all seasons indicates a need to alter crop types and water requirements
Rainfall Events	Slight change in the number of precipitation events in winter and spring indicate shift in runoff and irrigation patterns	Slight change in the number of precipitation events in winter and spring indicate shift in runoff and irrigation patterns	Slight change in the number of precipitation events in winter and spring indicate shift in runoff and irrigation patterns

14.6 SEA-LEVEL RISE

Changes in sea level can occur due to many factors including changes in the amount of water stored on land in the form of ice sheets and glaciers; shoreline subsidence or movement; and thermal expansion of water caused by increasing temperatures. According to an article by NOAA, the average rate of sea level rise (SLR) is currently about one-eighth of an inch per year, but this rate is projected to increase in the future. Being adjacent to the Pacific Ocean with approximately 100 miles of coastline, the SLO IRWM Region is vulnerable to SLR and has an interest in quantifying the changes in sea level that may occur in the coming years. The forecasting of SLR in the modeling community estimates the rise at different geographic scales, but there is no industry-accepted model currently in use.

A literature search indicates that, for the most part, the projected rise in sea level estimated by various studies using different approaches all fall within the same order of magnitude, as categorized and presented in **Table 14-6**. In general, a change of less than 1 foot is likely to occur at mid-century and less than 3 feet by end of century (2100). This change combined with forecasted increases in storm surge and high tidal effects could result in concerning on-shore impacts in the coming years.

Table 14-6 below shows SLR estimates based on the IPCC A1B scenario and several other emissions scenarios. A prevalent concern with SLR is the impact to coastal low-lying urban areas at risk of flooding during periods of coincident high tide or as a result of increased storm intensity. Further quantification of the implications of these changes is beyond the scope of this effort; however, through continued monitoring and adaptation, the SLO Region can adjust to the slow changes in sea level as they occur over the coming years.

Table 14-6: *Sea-level Rise Literature Search Results*

Scale	Emissions Scenario	Projected Rise (m)	Projected Rise (ft)	Period	Climate Model	Data Source
MID-CENTURY						
Port San Luis	Historical	0.011-0.047 m	0.036-0.15 ft	2050	Extrapolation of Historical Trend	NOAA
California	Historical	0.15 m	0.49 ft	Mid-century	Extrapolation of Historical Trend	California DWR
California	Multi-Scenario	0.24 - 0.31 m	0.78-1.02 ft	Mid-century	Semi Empirical (Rahmstorf's) Approach	California DWR
California	Multi-Scenario	0.087 - 0.095 m	0.28-0.31 ft	2020 - 2049	PCM	Journal Publication
California	Multi-Scenario	0.116 - 0.127 m	0.38-0.41 ft	2020 - 2049	HadCM3	Journal Publication
California	Multi-Scenario	0.04 - 0.3 m	0.13-0.98 ft	2030	Multi-model Ensemble	National Academy

Scale	Emissions Scenario	Projected Rise (m)	Projected Rise (ft)	Period	Climate Model	Data Source
California	Multi-Scenario	0.12 - 0.6 m	0.39-1.96 ft	2050	Multi-model Ensemble	National Academy
Global	A1B	0.063 - 0.284 m	0.2-0.93 ft	2050	Multi-model Ensemble	IPCC
LATE CENTURY						
California	Multi-Scenario	0.54 - 0.94 m	1.77-3.08 ft	End-Century	Semi Empirical (Rahmstorf's) Approach	California DWR
California	Multi-Scenario	0.192 - 0.288 m	0.63-0.94 ft	2070 - 2099	PCM	Journal Publication
California	Multi-Scenario	0.268 - 0.409 m	0.87-3.08 ft	2070 - 2099	HadCM3	Journal Publication
California	Multi-Scenario	0.42 - 1.67 m	1.37-5.47 ft	2100	Multi-model Ensemble	National Academy
Global	A1B	0.21 - 0.45 m	0.69-1.47 ft	2090 - 2099	Multi-model Ensemble	IPCC

14.7 Flooding due to Climate Change and Extreme Precipitation Events

Though global climate models present uncertainty in projected changes in flooding, the increased intensity of precipitation events indicate a relatively low threat in the SLO IRWM Region. The changes in rainfall and runoff presented in **Section 14.5** can be said to change floodplains set forth by the Federal Emergency Management Agency (FEMA). Regardless of climate change, with continued flood management and monitoring activities, FEMA floodplain maps will require updating and structural remedies to ensure the continued safety of life and property. Regulated rivers also require constant monitoring and modification in operations and structural/hydraulic design to mitigate for changed and unforeseen conditions in the weather patterns. **Figure 14-11** is used solely as a source for where to find the FEMA floodplain maps as they may change over time with climate change monitoring.

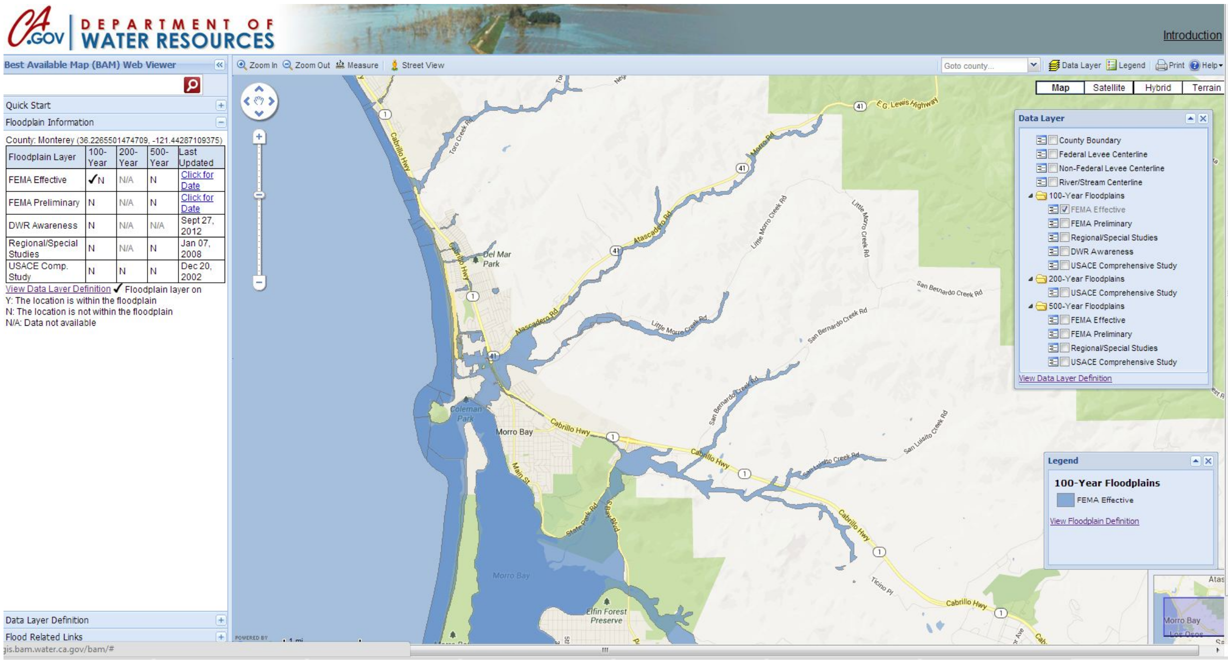


Figure 14-11: *Current FEMA 100-Year Floodplain in the Morro Bay Region*

14.8 Overview of Regional Climate Change Impacts

During the 2018 IRWMP Update, a literature review was completed in December 2017 by Water Systems Consulting, Inc. (WSC) evaluating current research on the Region's anticipated climate change effects and the corresponding water resources-related impacts. Based on the County's previous Climate Change Analysis, described above, and recent climate change literature, a list of some but not all of the notable climate change impacts relevant to water resources management is included below. The anticipated impacts are separated into seven vulnerability categories recommended in the Climate Change Handbook for Regional Water Planning. The complete literature review can be found in **Appendix J**.

Water Demand:

- Increased agricultural water demands due to reduced surface flows, reduced soil moisture, increased evapotranspiration rates, and longer growing seasons
- Increased seasonal water demand due to increased drought frequency and increased air temperatures
- Increased cooling and process water demand due to increased air and water temperatures and increased energy demands
- Decreased crop yields due to changes in growing seasons and heat patterns
- Increased difficulty meeting water curtailments due to increased drought frequency and increased water demand

Water Supply:

- Decreased groundwater recharge due to decreased precipitation and increased storm severity
- Increased water supply shortages due to decreased precipitation and increased water demands
- Increased seawater intrusion of coastal aquifers due to sea level rise
- Increased drought frequency and severity
- Decreased reliability of imported water supplies due to decreased snowmelt and increased water demands
- Increased difficulty meeting instream flow requirements due to decreased groundwater levels and precipitation

Water Quality:

- Increased eutrophication and harmful algal blooms due to increased air and water temperatures
- Decreased assimilative capacity due to declining low flows
- Increased turbidity and other contamination concerns due to increased storm severity
- Increased risk of contamination due to increased wildfire frequency
- Increased sedimentation and erosion
- Increased saltwater intrusion due to sea level rise and declining low flows

Sea Level Rise:

- Increased seawater intrusion of coastal aquifers
- Increased coastal erosion
- Increased stress on protective coastal structures
- Increased coastal flooding and storm severity

Flooding:

- Increased flooding due to increased storm severity
- Increased risk of flooding due to increased wildfire frequency
- Increased erosion and disruption of facilities due to flooding

Ecosystem and Habitats:

- Increased sedimentation and erosion causing disruption of ecosystems
- Increased saltwater intrusion of aquatic habitats
- Disruption of marine ecosystems by ocean acidification
- Increased stress on climate-sensitive species
- Increased changes in species distribution
- Increased spread of invasive species

Hydropower:

- Changes in hydropower generation due to changes in precipitation patterns
- Increased energy demand due to increased air and water temperatures

14.9 VULNERABILITY ASSESSMENT

In accordance with the 2016 IRWM Guidelines, SLO County completed a thorough climate change vulnerability assessment following the Climate Change Handbook. Using the indicator questions form Section 4.3 of the Handbook, the County identified and described the regional water resources-related vulnerabilities. RWMG members and other IRWM stakeholders provided input on the vulnerability descriptions through an online survey and the IRWM Climate Change Workshop (held January 31, 2018). See **Appendix J** for the complete Final Vulnerability Assessment approved by the RWMG in February of 2018.

The purpose of the assessment is to inform the development of a working list of prioritized vulnerabilities, which is used to inform the Plan Objectives, Resource Management Strategies, and Project Review Process. The major categories of water resources-related vulnerabilities are:

1) Water Demand
2) Water Supply
3) Water Quality
4) Sea Level Rise
5) Flooding
6) Ecosystems and Habitats
7) Hydropower

A total of 35 vulnerabilities were identified for the Region, and the complete list of prioritized vulnerabilities is in **Table 14-7**. Included below are summaries of the identified vulnerabilities separated by category. Detailed descriptions of the anticipated climate change impacts in each Sub-region are included in **Section 3**, and detailed responses to the Climate Change Handbook vulnerability indicator questions are in **Appendix J**.

14.9.1 Water Demand

The impacts of climate change on water demand will be a serious concern for San Luis Obispo County in the future. As temperatures increase and precipitation decreases, water demand is expected to increase for many of the region's most prominent industries including wineries, breweries, hospitals, energy production, hotels, education, and agriculture. Similarly, seasonal water demands are expected to increase as agriculture and tourism – two of the Region's largest industries – contribute to increased water usage over warmer, summer months for many of the Region's communities. Increases in water demand will result in growing levels of stress on water supplies, especially when water usage corresponds with periods of reduced groundwater levels. These adverse impacts have already been observed for several groundwater basins in the County that have been unable to keep up with water demand during recent drought conditions. As drought frequency and temperatures increase, meeting the water demand for critical domestic and industrial uses could become a mounting difficulty. As such, water curtailment efforts that have been previously effective could become increasingly difficult to meet and cause immense stress for communities.

14.9.2 Water Supply

Groundwater basins, surface water bodies, reservoirs, and the State Water Project are some of the major water supplies for San Luis Obispo County. These critical water supplies will not only be exposed to several harmful climate change effects, but many are also highly sensitive to anticipated effects. For example, coastal aquifers – an important water supply source for several communities in the region – are at risk of increased drought frequency leaving them increasingly sensitive to seawater intrusion, a mounting risk due to sea level rise. Across the Region, the limited storage capabilities for carryover supply surpluses will make the anticipated fluctuations in water supply increasingly stressful. Past drought conditions have already revealed vulnerabilities in regional water supplies as several communities have been forced to find additional or alternate water supplies. As drought frequency increases, precipitation decreases, and water demand increases, the impacts to the County's water supply sources will be increasingly disruptive.

14.9.3 Water Quality

Existing and previous water contamination issues in water bodies throughout the County serve as indicators of how climate change effects will make water quality a growing concern. For instance, previous heavy rain events have resulted in increased water contaminant levels in reservoirs and surface water supplies forcing communities to change their water treatment methods. As storm severity increases in the future, this water quality concern will only worsen. Some of the threats to water quality that will be exacerbated by climate change include increased sedimentation and erosion, increased eutrophication, more concentrated instances of runoff, and decreased assimilative capacity. This threaten not only consumptive water uses but also the health of aquatic ecosystems and species and economies and recreation reliant on water bodies.

14.9.4 Sea Level Rise

Tidal gauges along the County's coastline with historic and current data indicate that sea levels are rising in this area. This poses a series of threats to vital coastal communities, infrastructure, and ecosystems. Coastal erosion has already forced some communities to add coastline armoring, and as sea levels rise erosion is expected to worsen. Due to sea level rise, increased flooding and storm severity are also anticipated and will threaten low-lying habitats and communities. Many areas including Oceano, Pismo Beach, and Los Osos already experience flooding during high tides and storms events indicating the severity of this growing threat. Finally, sea level rise will increase the threat of seawater intrusion for critical coastal aquifers, which could compromise the water supply for coastal communities.

14.9.5 Flooding

San Luis Obispo County is at a high risk of increased flooding in the future. Changes in precipitation patterns, sea level rise, and increased wildfire risk all contribute to growing flood concerns for the Region. As a result, flood protection and control infrastructure will be critical moving forward. However, much of the critical flood protection infrastructure, such as the Arroyo Grande Creek Channel Levee and the City of San Luis Obispo's creek corridors, are aging and in need of updates or repairs. This makes communities increasingly vulnerable to flood risks. Similarly, communities across the County currently have insufficient flood control facilities highlighting the hazard of increased flooding for the Region.

14.9.6 Ecosystems and Habitats

A myriad of anticipated climate change effects threatens the wellbeing of species and aquatic habitats in the County. Many of the Region's species and ecosystems are sensitive to even small changes in habitat conditions, and anticipated climate change effects including increased air and water temperature, decreased precipitation, increased sedimentation, and decreased fog could all have serious detrimental impacts. Home to numerous threatened and endangered species and recognized Critical Habitat Areas, San Luis Obispo County is highly reliant on its natural biodiversity and aquatic ecosystems for economic and recreational uses. This leaves the Region vulnerable to disruptions of these natural systems, which could be devastating to important industries like tourism, fishing, and oyster harvesting as well as customs and lifestyles of local communities.

14.9.7 Hydropower

Currently, San Luis Obispo County does not obtain energy from hydropower sources. As such, the impacts of anticipated climate change effects on hydropower generation are not a concern for the Region. However, the City of San Luis Obispo is exploring future options for conduit hydropower generation.

14.9.8 Housing and Development

During the Region's Climate Change workshop on January 31st, 2018, RWMG members and Interested Stakeholders discussed the possible inclusion of a "Housing and Development" vulnerability to the assessment. Ultimately, the decision at the workshop, and later confirmed by the RWMG at their regular meeting on February 7th, 2018, was to include a narrative discussion of how housing and development is affected by the prioritized vulnerabilities throughout the Region.

The RWMG identified 5 vulnerabilities that directly relate to Housing and Development:

- Water Demand 1: Water-dependent Industries

- Water Demand 4: Drought-sensitive groundwater basins
- Water Demand 5: Communities with water curtailment efforts
- Water Supply 2: Water supply from coastal aquifers
- Water Supply 3: Inability to store carryover supply surpluses

Climate change, as documented in this section, can dramatically affect the ability of incorporated and unincorporated communities to realize projected growth, even if growth is recognized and accounted for in a general plan. The most recent drought (2012-2017) brought many restrictions to water use Region-wide. Water curtailment requirements (vulnerability WD-5) were enacted at both the State and local government level. State Water Project allocations were reduced thereby increasing local dependence on groundwater. This increased reliance on groundwater caused areas of the Region to experience a moratorium on well drilling permits (WD-4). Additionally, coastal communities severely restricted landscape use (WS-2) and purveyors across the Region stopped issuing permits for construction water (WD-1).

Looking ahead, the San Luis Obispo Counsel of Governments (SLOCOG) is projecting a population growth between 10% (low estimate) and 33% (high estimate) for the Region by the year 2050. To realize this, the Region will need to continue to address these Water Supply and Water Demand vulnerabilities related to climate change. For more information, see the SLOCOG's Regional Growth Forecast.

14.10 Vulnerability Prioritization

RWMG members and other IRWM stakeholders were able to participate in the prioritization of the 35 regional vulnerabilities by completing an online survey or attending the IRWM Climate Change Workshop (held January 31, 2018). Based on stakeholder input, the vulnerabilities were separated into four priority categories: very high, high, medium, and low. These prioritizations were determined using three characteristics evaluated in the online survey and discussed at the Workshop.

The characteristics used to inform the vulnerability prioritization are:

1) **Exposure –** the extent to which a resource, asset, or system could be subject to the effects of climate change
2) **Sensitivity –** the degree to which a resource, asset, or system would be impacted by the effects of climate change
3) **Likelihood –** the probability that a resource, asset, or system would be impacted by the effects of climate change *due to* lack of adaptive capacity

Results from the online survey and workshop worksheets as well as detailed information on how the priorities were determined are included in **Appendix J**. The RWMG's final list of prioritized vulnerabilities is shown in **Table 14-7**below.

Table 14-7: *Climate Change Vulnerability Prioritization*

Vulnerability	Priority
Water Demand	
Drought-sensitive groundwater basins	Very High
Insufficient instream flows	Very High
Water-dependent industries	High
Climate-sensitive crops	Medium
Communities with water curtailment efforts	Medium
Seasonal water demand	Medium
Water Supply	
Drought-sensitive water systems	Very High
Water supply from coastal aquifers	Very High
Inability to store carryover supply surpluses	High
Invasive species management issues	Medium
Water supply from snowmelt	Low
Water Quality	
Declining seasonal low flows	Very High
Water bodies impacted by eutrophication	High
Water bodies in areas at risk of wildfires	High
Water quality impacted by rain events	High
Water bodies with restricted beneficial uses	Medium
Sea Level Rise	
Coastal erosion	Medium
Coastal infrastructure in low-lying areas	Medium
Flooding due to high tides and storm surges	Medium
Low-lying coastal habitats	Medium
Rising sea levels	Medium
Coastal land subsidence	Low
Coastal structures	Low
Flooding	
Increased flood risk due to wildfires	Very High
Aging flood protection infrastructure	High
Insufficient flood control facilities	High
Ecosystem and Habitat	
Changes in species distributions	High
Environmental flow requirements	High
Estuarine habitats dependent on freshwater flow patterns	High
Aquatic habitats at risk of erosion and sedimentation	Medium
Climate-sensitive fauna and flora	Medium
Fragmented aquatic habitats	Medium
Aquatic habitats used for economic activities & recreation	Low
Exposed coastal ecosystems	Low
Hydropower	
Future hydropower plans	Low

14.10.1 RWMG Feasibility

Once the prioritized list of vulnerabilities was confirmed, **Table 14-8** was constructed to evaluate the feasibility of the SLO RWMG to address its very high and high priority vulnerabilities.

Table 14-8: *RWMG Feasibility to Address Climate Change Vulnerabilities*

Vulnerability	Priority	Limitations of RWMG
Aging flood protection infrastructure	High	Addressing this vulnerability will require overcoming large financial and permitting barriers, which is possible for the RWMG and its members but will not be easy.
Changes in species distributions	High	Limitations in available knowledge and uncertainty of climate change impacts will impede the feasibility of the RWMG to appropriately manage changes in species distribution. Regulatory alignment will also be a challenging aspect of addressing this vulnerability.
Declining seasonal low flows	Very High	The RWMG's lack of regulatory power and limited ability to influence human behavior both create barriers to combating the declining seasonal low flows threatening waterways and ecosystems in the area.
Drought-sensitive groundwater basins	Very High	The RWMG's lack of regulatory power could be a significant barrier to addressing the region's vulnerability to drought-sensitive basins. Another challenge will be getting various agencies and communities that depend on the same basin to collaborate and coordinate efforts.
Drought-sensitive water systems	Very High	The RWMG has little ability to change domestic water usage beyond the ability of certain member agencies to implement water usage restrictions within their jurisdictions. Further, securing additional water supplies requires the availability of such supplies as well as the financial resources and regulatory permission to obtain those supplies.
Environmental flow requirements	High	The RWMG's lack of regulatory power and limited ability to influence human behavior both create barriers to ensuring environmental water demands are met. Access to tools and information needed for accurate modeling could also become issues.
Estuarine habitats dependent on freshwater flow patterns	High	Lack of regulatory power and limitations in data and information availability will restrict the RWMG's feasibility to properly manage estuarine habitats in the face of climate change impacts.

Vulnerability	Priority	Limitations of RWMG
Inability to store carryover supply surpluses	High	Regulatory alignment and cooperation between agencies will be critical for increasing the region's ability to store carryover supply surpluses; however, the RWMG is limited in its ability to ensure either.
Increased flood risk due to wildfires	Very High	Lack of control over regulations and environmental conditions greatly limits the RWMG's ability to prevent wildfires. Instead, the RWMG's major tools to address this vulnerability are educating the community on the risks of flooding related to wildfires and promoting emergency response procedures are established.
Insufficient flood control facilities	High	Addressing this vulnerability will require overcoming large financial and permitting barriers, which is possible for the RWMG and its members but will not be easy.
Insufficient instream flows	Very High	Combating the regional vulnerability to insufficient instream flows will be inhibited by the RWMG's lack of regulatory power. Maintaining sufficient streamflows will require interagency collaboration and regulatory alignment.
Water bodies impacted by eutrophication	High	Lack of regulatory power will inhibit the RWMG's feasibility to reduce eutrophication, but they can promote public education on the contributing factors.
Water bodies in areas at risk of wildfires	High	Lack of control over regulations and environmental conditions greatly limits the RWMG's ability to prevent wildfires. Instead, the primary way in which the RWMG can address this vulnerability is by ensuring emergency response procedures and resources are in place to react swiftly to minimize spread and damage.
Water quality impacted by rain events	High	Limitations on the RWMG's regulatory power reduce the group's capacity to address this vulnerability. Although, improved stormwater resource management will be promoted by through the regional Stormwater Resource Plan.
Water supply from coastal aquifers	Very High	The ability to reduce dependence on coastal aquifers through the acquisition of additional water supplies is limited by the availability of such supplies as well as the financial and political requirements of obtaining those supplies. The RWMG's limited political power and access to grant funding will pose challenges to addressing this issue.
Water-dependent industries	High	Technological limitations could impede the region's ability to address the vulnerability of water-dependent industries to the effects of climate change. Human perception and understanding of the risks posed by climate change could also prove to be barriers to adaptation, which the RWMG can only combat to a certain extent.

14.11 ADAPTATION AND MITIGATION STRATEGIES

Incorporating climate change vulnerabilities into the IRWM Plan Objectives, Resource Management Strategies, and Performance Metrics provides the necessary assurances to address adaption strategies and methods of mitigating climate change. The SLO RWMG decided the Plan Objectives should be reviewed to ensure all six "very high" priority climate change vulnerabilities were addressed. An evaluation completed by WSC determined that the existing Plan Objectives sufficiently captured the need to address the region's "very high" priority vulnerabilities; see **Appendix J** for the full memorandum from WSC. **Table 14-9** shows the matrix demonstrating the relationship between the Plan Objectives and six vulnerabilities. **Table 14-10**, evaluates how the Plan Objectives address five requirements related to climate change as specified in the 2016 IRWM Grant Program Guidelines. Specifically, this review ensured the Plan Objectives addressed the region's need to adapt to changes in runoff and recharge as well as sea level rise.

Similar to the Plan Objectives, a matrix was constructed to verify that the Plan's Resource Management Strategies include appropriate adaptation strategies. The relationship between the seven categories of vulnerabilities and the CWP RMS is shown in **Table 14-11** below. This table reveals how the RMS incorporate adaptation strategies relevant to the San Luis Obispo Region. A second table, **Table 14-12**, demonstrates the relationship between the RMS and three primary climate change mitigation methods. Together these tables illustrate the variety of methods, which can be exercised to address water-related climate change vulnerabilities.

Additionally, the Project Review Process includes consideration of both climate change mitigation and adaptation. This is discussed in **Section 14.13** below.

Table 14-9: Plan Objectives Related to Very High Vulnerabilities

IRWM Plan Objectives	Very High Priority Vulnerabilities	Drought-sensitive groundwater basins	Insufficient instream flows	Water supply from coastal aquifers	Drought-sensitive water systems	Declining seasonal low flows	Increased flood risk due to wildfires
Water Supply	Maximize accessibility of water	●	●	●	●	●	
	Adequate water supply	●	●	●	●	●	
	Sustainable potable water for rural	●	●	●	●	●	
	Sustainable water for agriculture	●	●		●	●	
	Water system WQ improvements	●	●	●			
	Implement water management Plans	●	●	●	●	●	
	Conservation/water use efficiency	●	●	●	●	●	
	Plan for vulnerabilities of water supply	●	●	●	●	●	●
	Diverse supply (recycled, desalination)	●	●	●	●	●	
	Support Watershed Enhancement	●	●	●	●	●	●
Ecosystem and Watersheds	Understand watershed needs	●	●	●	●	●	●
	Conserve balance of ecosystem	●	●	●	●	●	●
	Reduce contaminants	●	●	●	●		
	Public involvement and stewardship				●		●
	Protect endangered species		●	●			●
	Reduce impacts of invasive species						●
	Climate change in ecosystems	●	●	●	●	●	●
Groundwater	Understand GW issues and conditions	●	●	●	●	●	
	Support local GW management	●	●	●	●	●	
	Further local basin management objectives	●	●	●	●	●	●
	CASGEM Program	●	●	●	●	●	
	Groundwater recharge	●	●	●	●	●	
	Protect and improve GW quality	●	●	●	●	●	
Flood Management	Understand flood management needs		●				●
	Promote low impact development	●		●	●	●	●
	Enhance natural recharge	●		●	●	●	
	Improve infrastructure and operations	●	●	●	●	●	●
	Implement multiple-benefit projects	●	●	●	●	●	●
	Restore streams, rivers and floodplains	●	●	●	●	●	●
	Support DAC flood protection						●
Water Resources Management	Public outreach on IRWM implementation	●	●	●	●	●	●
	Funding for IRWM implementation	●	●	●	●	●	●
	Support local control				●		●
	Consider property owner rights	●	●	●			●
	Agency alignment on water resource efforts	●	●	●	●	●	●
	Collaboration between urban, rural, and ag	●	●	●	●	●	●
	DAC support and education	●	●	●	●	●	
	Promote public education programs	●	●	●	●	●	●

***Table 14-10**: Plan Objectives Related to Climate Change Requirements*

IRWM Plan Objectives	Adaptations & Mitigation Requirements	Adapting to changes in runoff and recharge	Consider the effects of sea level rise on water supply conditions	Reduce energy consumption	Strategies of CARB Scoping Plan	Options for carbon sequestration and renewable energy
Water Supply	Maximize accessibility of water			●		●
	Adequate water supply		●	●		●
	Sustainable potable water for rural	●	●		●	
	Sustainable water for agriculture	●	●		●	
	Water system WQ improvements		●			
	Implement water management Plans	●	●	●	●	●
	Conservation/water use efficiency	●	●	●	●	●
	Plan for vulnerabilities of water supply	●	●	●	●	●
	Diverse supply (recycled, desalination)	●	●	●	●	
	Support Watershed Enhancement	●	●			
Ecosystem and Watersheds	Understand watershed needs	●	●			●
	Conserve balance of ecosystem	●	●			●
	Reduce contaminants	●	●			
	Public involvement and stewardship					
	Protect endangered species		●			●
	Reduce impacts of invasive species	●	●			●
	Climate change in ecosystems	●	●	●	●	●
Groundwater	Understand GW issues and conditions	●	●		●	
	Support local GW management	●	●	●	●	●
	Further local basin management objectives	●	●		●	●
	CASGEM Program	●	●			
	Groundwater recharge	●	●			
	Protect and improve GW quality	●	●			
Flood Management	Understand flood management needs	●	●			
	Promote low impact development	●		●	●	●
	Enhance natural recharge	●		●	●	●
	Improve infrastructure and operations	●	●	●	●	
	Implement multiple-benefit projects	●	●	●	●	●
	Restore streams, rivers and floodplains	●	●			●
	Support DAC flood protection	●	●			
Water Resources Management	Public outreach on IRWM implementation		●	●	●	
	Funding for IRWM implementation	●	●	●	●	
	Support local control			●	●	
	Consider property owner rights					
	Agency alignment on water resource efforts	●	●	●	●	●
	Collaboration between urban, rural, and ag	●	●	●	●	●
	DAC support and education		●	●	●	
	Promote public education programs	●		●	●	

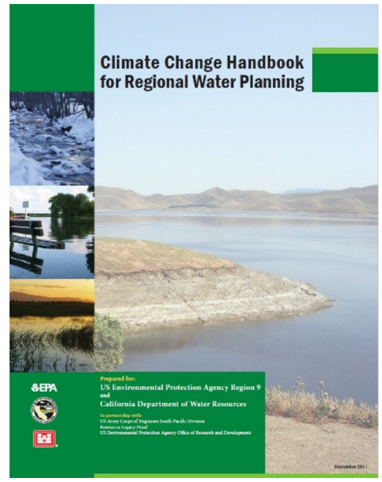
__Table 14-11:__ Resource Management Strategies Related to Climate Change Vulnerabilities

Resource Management Strategies	Water Demand	Water Supply	Water Quality	Sea Level Rise	Flooding	Ecosys-tem and Habitat	Hydro-power
California Water Plan 2009 RMS							
Agricultural lands stewardship	●		●		●	●	
Agricultural water use efficiency	●	●				●	
Conjunctive management and groundwater storage	●	●	●	●			
Conveyance – Delta		●					
Conveyance – Regional/Local	●	●					
Crop idling for water transfers	●	●	●				
Desalination		●		●			
Drinking water treatment and distribution	●	●	●	●		●	
Economic incentives	●	●				●	
Ecosystem restoration			●	●	●	●	
Forest management		●	●		●	●	
Groundwater remediation/aquifer remediation		●	●	●			
Improve flood management				●	●	●	
Irrigated land retirement		●	●				
Land use planning and management	●		●	●	●	●	
Matching water quality to use			●	●	●	●	
Pollution prevention		●	●		●	●	
Precipitation enhancement		●					
Recharge area protection		●	●		●		
Recycle municipal water		●					
Salt and salinity management			●	●		●	
Surface storage – CALFED/State	●	●					
Surface storage – Regional/Local	●	●					
System reoperation	●	●	●	●	●	●	●
Urban stormwater runoff management		●	●		●	●	
Urban water use efficiency	●	●				●	
Water transfers		●					
Water-dependent recreation		●	●		●	●	
Watershed management	●	●	●	●	●	●	
California Water Plan 2013 Update RMS							
Outreach and engagement	●		●			●	●
Sediment management		●	●	●	●	●	
Water and culture	●		●			●	

__Table 14-12:__ Resource Management Strategies Related to Mitigation Strategies

Resource Management Strategies	Energy Efficiency	Emissions Reduction	Carbon Sequestration
California Water Plan 2009 RMS			
Agricultural lands stewardship	●	●	●
Agricultural water use efficiency	●	●	
Conjunctive management and groundwater storage			
Conveyance – Delta	●	●	
Conveyance – Regional/Local	●	●	
Crop idling for water transfers		●	
Desalination			
Drinking water treatment and distribution	●	●	●
Drinking water treatment and distribution	●	●	●
Economic incentives	●	●	●
Ecosystem restoration			●
Forest management			●
Groundwater remediation/aquifer remediation			
Improve flood management			●
Irrigated land retirement			
Land use planning and management	●	●	●
Matching water quality to use	●		●
Pollution prevention		●	●
Precipitation enhancement		●	
Recharge area protection			●
Recycle municipal water	●	●	
Salt and salinity management		●	
Surface storage – CALFED/State		●	
Surface storage – Regional/Local		●	
System reoperation	●	●	
Urban stormwater runoff management	●	●	
Urban water use efficiency	●	●	
Water transfers	●	●	
Water-dependent recreation		●	
Watershed management	●	●	●
California Water Plan 2013 Update RMS			
Outreach and engagement		●	
Sediment management		●	●
Water and culture	●	●	●

14.12 Future Data Gathering and Analysis



Chapter 5 of the State Climate Change Handbook, "Measuring Regional Impacts", DWR provides a methodology for data gathering and analysis to monitor climate change and assess its impacts through the IRWM Planning process. Quantifying climate change variables is critical for quantifying performance metrics and preventing undesirable climate change impacts. This section is a very brief summary highlighting the beginning of a long data collection and modeling process of making future projections and then monitoring the essential climate change variables to validate or invalidate the projections. This process of making projections and constant monitoring will continue in perpetuity. Modeling and monitoring work hand-in-hand to continuously define better models that determine the Objectives and Performance Metrics of the IRWM Plan.

By carefully selecting the available models, and interpreting the results, this section provides the baseline of monitoring climate variables most meaningful to describing the region's most important water-related concerns as follows:

1. Water Demand
2. Water Supply
3. Water Quality
4. Ecosystem and Habitat Vulnerability
5. Sea-level Rise
6. Flooding

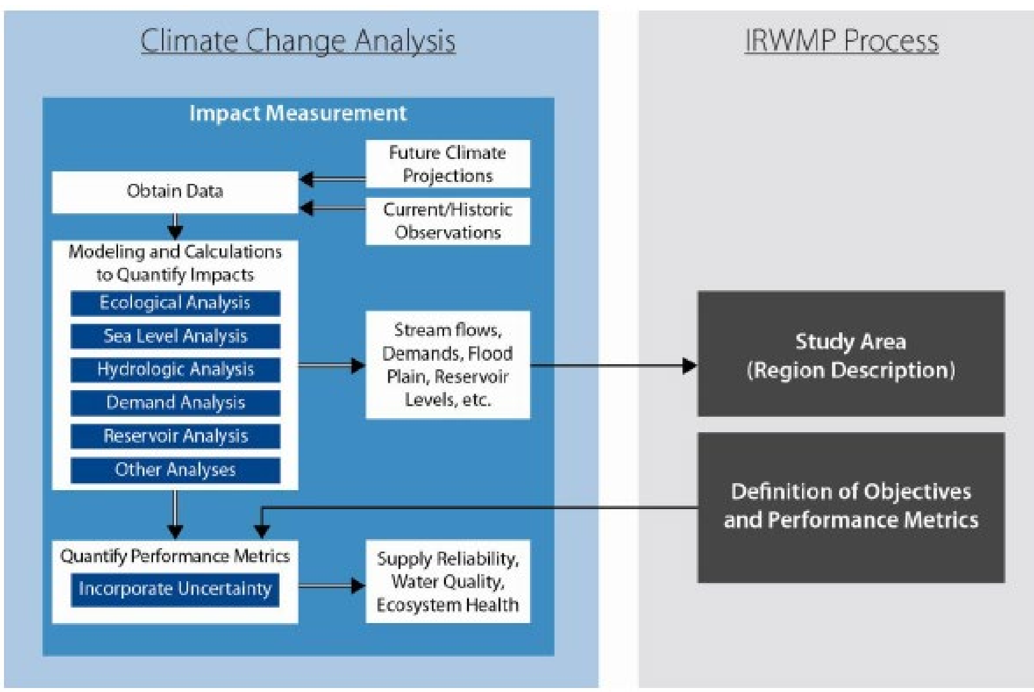


Figure 14-12: *Climate Change Data and IRWM*

14.12.1 Water Demands

Obtaining data for water demands (or demand analysis) is shown in **Figure 14-12** as informing models and performing calculations to quantify impacts. This information is then shown to be used in the IRWM planning process for purposes of the Region Description and, like all water-related concerns, for defining the Objectives and Performance Metrics.

Water demands and climate variables are collected as part of the Data Management Program described in **Section 9 – Data Management**. The monitoring results provide the correlation between water demands and increased temperatures, changed precipitation patterns, increased evaporation and plant transpiration (also referred to as ET), and decreased runoff, as described in **Section 14.5**. Of all the water demand sectors, urban demands are most accurate due to current state-mandated monitoring requirements, and they offer the best opportunity to begin monitoring changes in climate as a function of changes in water demand. The State Handbook states:

> *The general approach of regression analysis involves developing a regression relationship between water demand versus temperature and precipitation. Planners can then use this relationship to evaluate future conditions.*

Agricultural demands are a function of precipitation, temperature, and ET climate variables, but vary significantly based on crop types and crop-specific ET requirements. To simplify and provide a meaningful correlation, a preferred approach is to identify changes in ET to both temperature and precipitation. This information, in turn, allows for the calculation of agricultural water demands based on the ET, irrigated area, crop type, precipitation, and temperature. The same relationship between the climate change variables and agricultural water demands can be used to model future conditions.

14.12.2 Water Supplies

Measurement of water supplies and quantifying supply reliability focuses on: 1.) water supply sources within the region, 2.) water imported into the region, and 3.) supplies for environmental needs. Many of the tools and data collection systems already in place throughout the region monitor these three supply elements and report based on need and available resources. Correlating changes in the amount of water supply with the climate variables of rainfall, temperature, and runoff provides the relationships to make model adjustments in rainfall runoff, imported water reliability, and in-stream flow requirements for environmental demands. Many local and state models use the climate variables in their projection of available water supplies and especially for California State Water Project contractors who rely on these supplies, including San Luis Obispo County.

14.12.3 Water Quality

Surface water quality affects both drinking water supplies and ecological/environmental needs. The IRWM Region's near-coastal drinking water intakes and estuarine habitats are both susceptible to salt water intrusion. Fish in local rivers and streams are susceptible to higher temperatures. Rivers, reservoirs, lakes, and coastal areas are all susceptible to low dissolved oxygen that accompany higher temperatures.

As quoted in the State Handbook, Water quality models are by their very nature "*labor intensive and require a high level of technical expertise*." The expectation to monitor climate variables associated with water quality is high with water quality monitoring programs planned to increase in breadth over time. Monitoring programs outside of the IRWM Planning process will provide necessary data for modeling; however; the application of the water quality data and performing correlations with climate change variables and validating water quality models are not proposed within the IRWM Planning process.

14.12.4 Ecosystem and Habitat Vulnerability

The approaches to measuring potential impacts of climate change on the environment, including flora and fauna, are varied. While more vulnerability metrics and methods for assessing them can be found in the literature, the IRWM Plan's implementation of data management and monitoring programs can only consider stream water temperature, water quantity, estuarine salinity, and coastal habitat loss from sea-level rise.

Data collection activities surrounding the protection of water supplies from salinity intrusion also protects the estuary and coastal wetland areas dependent on freshwater. Changes in the water quality could have a significant impact on aquatic life, but require the same models described above in **Section 14.12.3**. Streamflow estimations can be easily calculated and modeled to assess potential ecosystem impacts as a result of reduced rainfall and runoff. While modeling tools are available to estimate future marsh and wetland migration or loss, this modeling effort is also allocated outside the planned work effort of the IRWM Plan process. Simple comparisons can take place, such as between the areas of coastal habitat and the projected sea-level rise impacts.

14.12.5 Sea-level Rise

Data collection of SLR takes place through local monitoring of the Central Coast Region. In addition, publication of global SLR data informs the region of continued threat to similar coastal regions. The State Handbook explains:

> *One method for quantifying SLR climate change impacts is to superimpose projected SLR onto elevations for existing coastal floodplains.... With new floodplains mapped, it is possible to compare existing infrastructure and resource locations with these flood plains.*

Tracking and reporting SLR data is considered to be a long-term monitoring effort with frequent reporting and comparisons with climate change model forecasting. Models calibrated to the measured SLR stand to benefit from this data collection effort. Though necessary models and data will be utilized, the process of collecting the information will not be included as part of the San Luis Obispo IRWM Plan implementation.

14.12.6 Increased Flooding

The fact that global climate change models work on the low resolution of a monthly time step, they do not capture the higher resolution storm events occurring over days within the months. Extreme storm events (e.g., the “Pineapple Express”) can occur over a period of hours or days. Monitoring of severe storm events currently occurs as part of the flood protection responsibilities of the region. However, there are few examples of alternative tools and methods to correlate storm events to changes in the climate variables, and most are either not available or need to be specifically tailored to incorporating climate change considerations into flood planning in the region. Therefore, the direct monitoring of flood events itself for purposes of monitoring climate change will not be incorporated within the IRWM planning process. Nonetheless, the region recognizes that the assessment of climate change impacts on future flooding is an important aspect of regional water planning.

14.12.7 Annual Climate Change Update

The SLO RWMG plans to hold an annual climate change meeting to review new information and tools pertinent to the region’s efforts aimed at addressing climate change vulnerabilities. During this meeting, relevant data gathering efforts will be discussed and the IRWM’s priority vulnerabilities will be reviewed considering current efforts and information. This measure will ensure the RWMG’s efforts related to climate change remain well-informed and appropriate for the region.

14.13 Project Ratings based on Climate Change

The projects listed in **Table 6-3** of **Section 6 – Project Review Process** were individually evaluated and rated based on 14 evaluation criteria. Listed below are the two evaluation criteria used to assess how the projects address climate change:

1) Potential of adaptation to the anticipated effects of climate change in the region
2) Potential of mitigating undesirable climate change impacts by reducing net greenhouse gas emissions

14.13.1 Adaptation Analysis

The potential for each project to contribute to climate change adaptation was evaluated based on its ability to address the region's prioritized vulnerabilities. See the prioritized vulnerabilities listed in **Table 14-8:** RWMG Feasibility to Address Climate Change Vulnerabilities**.** For the implementation project list scoring, each project could receive up to six points for climate change adaptation. The number of vulnerabilities addressed or alleviated by the project as well as the priority of those vulnerabilities determined the point value assigned to the project for the climate change adaptation criterion. In addition to addressing the 35 vulnerabilities, projects can also receive points for addressing changes in runoff and recharge and for addressing the impacts of sea level rise. Please see **Section 6 – Project Review Process** for more details on project scoring.

14.13.2 Mitigation Analysis

Projects scored for the implementation project list could receive a total of three points for climate change mitigation. Three considerations, each worth one point, were used to assess a project's mitigation potential:

1) Does the selected project reduce GHG emissions compared to other project alternatives?
2) Does the project qualitatively reduce energy consumption, especially energy embedded in water?
3) When evaluating the project-related GHG emissions on a 20-year planning horizon, does the project reduce GHG emissions?

A detailed description of the scoring process can be found in **Section 6.**

14.14 REFERENCES

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