# Section R: Climate Change

The Proposition 84/1E Integrated Regional Water Management (IRWM) Program Guidelines state: "California is already seeing the effects of climate change on hydrology (snowpack, river flows, storm intensity, temperature, winds, and sea levels). Planning for and adapting to these changes, particularly their impacts on public safety, ecosystem, and long-term water supply reliability, will be among the most significant challenges facing water and flood managers this century" (p. 68).

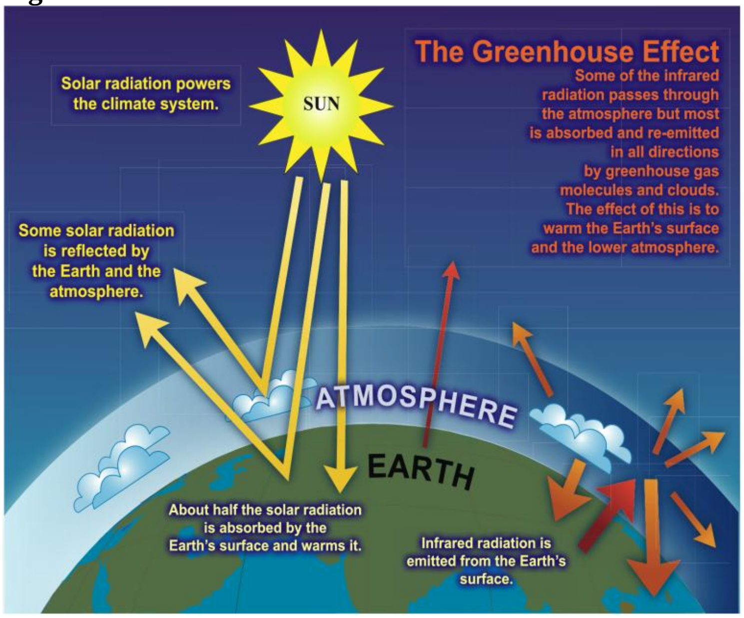
By design, IRWM planning efforts are collaborative and include many entities dealing with water management. These aspects make IRWM a good platform for addressing broad-based concerns like climate change, where multiple facets of water management are affected. The intent of the Climate Change standard in the Proposition 84/1E IRWM Program Guidelines is to ensure that IRWM Plans describe, consider, and address the effects of climate change on their regions and disclose, consider, and reduce when possible greenhouse gas (GHG) emissions when developing and implementing projects. This chapter describes global climate change and its anticipated impacts for the Greater Monterey County region, including an initial vulnerability analysis and risk assessment, and offers preliminary adaptation measures and climate change mitigation and GHG reduction strategies for the planning region. These strategies will be refined as more climate change data, and more refined analysis tools, become available.

## R.1 GLOBAL CLIMATE CHANGE: AN OVERVIEW

Climate change refers to any significant change in measures of climate, such as average temperature, precipitation, or wind patterns over a period of time. Climate change may result from natural factors and/or from human activities that change the composition of the atmosphere and alter the surface features of the land. Such changes vary considerably by geographic location. Over time, the earth's climate has undergone periodic ice ages and warming periods, as observed in fossil isotopes, ice core samples, and through other measurement techniques. Recent climate change studies use the historical record to predict future climate variations and the level of fluctuation that might be considered statistically normal given historical trends.

Significant changes in global climate patterns have recently been associated with global warming, an average increase in the temperature of the atmosphere near the Earth's surface. This gradual warming is the result of heat absorption by certain gases in the atmosphere and re-radiation downward of some of that heat, which in turn heats the surface of the Earth. These gases are called "greenhouse gases" because they effectively "trap" heat in the lower atmosphere causing a greenhouse-like effect. Some GHGs occur naturally and are emitted to the atmosphere through natural processes; others are created and emitted solely through human activities; while the production rate of some naturally occurring GHGs can be increased by human activities (California Natural Resources Agency 2009).

**Figure R-1: The Greenhouse Effect**




Source: Le Treut et al. 2007, p. 115.

The greenhouse effect helps to regulate the temperature of the planet. It is essential to life; without it, our planet would have an average temperature of about 14°F, as opposed to a comfortable 60°F. However, an accumulation of GHGs in the atmosphere is intensifying the greenhouse effect, threatening to raise average temperatures well beyond our "comfort zone." Nearly all climate scientists agree that human activities are to blame for the changing climate. The addition of carbon dioxide, the most prevalent GHG, into the atmosphere as a result of burning oil, natural gas, and coal, in combination with the depletion of our dense forests and wetlands which act as natural carbon dioxide sinks, are leading to an unnaturally high concentration of GHGs that are in turn intensifying the natural greenhouse effect on earth.

The Intergovernmental Panel on Climate Change (IPCC) stated in its 2007 Synthesis Report:

> *Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level. (*IPCC 2007a, p. 30)

Eleven of the twelve years between 1995-2006 were the warmest in recorded history. The temperature increase is widespread over the globe and is greater at higher northern latitudes. Average Arctic temperatures have increased at almost twice the global average rate in the past 100 years. In 2007, the IPCC stated that "observations since 1961 show that the average temperature of the global ocean has increased to depths of at least 3000 meters and that the ocean has been absorbing more than 80 percent of the heat added to the climate system" (IPCC 2007b, p. 5).

The IPCC has linked this increase in global temperature to a wide array of changes to our natural world, including a widespread decrease in the amount of snow cover and thickness and range of glaciers across the globe. Since 1978, the Arctic ice cap has decreased in size by about 3 percent per year with an average summer decrease of 7.4 percent. A 10 percent decrease in global snow cover and earlier spring thaws of rivers and lakes in the northern hemisphere have also been observed. Over the past 50 years, heat waves and serious rain events have been more common and in the past 30 years, there has been an increase in the number of northern Atlantic tropical storms (IPCC 2007a).

The combination of ice melt and the thermal expansion of seawater (due to warmer water temperatures) has led to global sea level rise.[1] Over the period from 1855 (beginning of the tide gauge record) to 2009, global sea level has risen approximately 8 inches (21 cm) (Church and White 2011). During this period the rate of sea level rise has also increased (Church and White 2006 and 2011; Bindoff et al. 2007). From 1961 to 1993 average global sea level rose at approximately 0.07 inches per year (1.9 mm/ yr) (Church and White 2011). Since 1993, sea level rise has accelerated to a rate of approximately 0.13 inches per year (3.2 cm/yr) (Church and White 2006; IPCC 2007a). The IPCC's 2007 Fourth Assessment Report (IPCC 2007b) projected sea level rise by the end of the century as a result of thermal expansion to range from 7 to 23 inches (18-59 cm). However, recent evidence suggests these values may prove to be underestimates of the potential rise in global sea level. Since the publication of the AR4 in 2007, advances in the understanding of the complexities of ice sheet dynamics have led to improved projections of sea level rise during the 21st century. These studies suggest actual sea level may rise as much as 28 to 79 inches (72-190 cm) by 2100 (Vermeer and Rahmstorf 2009; Jevrejeva et al. 2008; Grinsted et al. 2009; and Nicholls et al. 2011).

IPCC scientists predict that the serious consequences of climate change will continue to grow and expand. The rapid and unprecedented increase in surface temperature is accelerating the planet's water cycle, which will make extreme storms and droughts more frequent and severe (U.S. Global Climate Research Program 2009). These events will likely disrupt and damage food and fresh water supplies. The extreme increases in temperature to come will continue to melt portions of the Greenland ice shelf and cause the oceans to thermally expand, both of which will raise the average level of all oceans. This continuing rise in sea level will have multiple effects, including coastline destruction, the displacement of major population centers, and economic disruption.

### R.1.2 State Response to Climate Change: Legislation and Policy

California State's top scientists consider climate change to be a very serious issue requiring major changes in resource, water supply, and public health management (California Climate Change Center 2006). Below describes some of the more significant pieces of legislation and policy that have been enacted by the State in response to climate change.

California's first statute on climate change was enacted in 1988 when the State Legislature ordered a report on the impacts of climate change and recommendations to avoid, reduce, and address them. In 2002, the State led the country in becoming the first jurisdiction to require standards for GHG emissions from cars. In 2004, Senate Bill 1107 directed the Secretary of Environmental Protection to coordinate all climate change activities in the state. The Secretary chairs the Climate Action Team, which is made up of agency secretaries and department directors from throughout State government. With the passage of California Global Warming Solutions Act of 2006, also known as Assembly Bill (AB) 32, California became the first state to set a binding, economy-wide target for GHGs (California Environmental Protection Agency 2010).

***Executive Order S-3-05***

California is a substantial contributor of global GHGs, emitting over 400 million metric tons of carbon dioxide a year (California Air Resources Board 2007). In June 2005, Governor Schwarzenegger established California's GHG emissions reduction targets in Executive Order S-3-05. The Executive Order established the following goals:

[1] Note: This paragraph has been almost entirely excerpted from "Preparing for the Future: Climate Change and the Monterey Bay Shoreline. Summary Report for Participants," a summary report of a December 6, 2011 workshop, prepared by Center for Ocean Solutions and the Monterey Bay National Marine Sanctuary. All of the references in this paragraph are cited in the "Preparing for the Future" report.

- Greenhouse gas emissions should be reduced to 2000 levels by 2010;
- Greenhouse gas emissions should be reduced to 1990 levels by 2020; and
- Greenhouse gas emissions should be reduced to 80 percent below 1990 levels by 2050.

***Global Warming Solutions Act of 2006 (Assembly Bill 32)***

The State Legislature enacted Assembly Bill (AB) 32, the California Global Warming Solutions Act of 2006, which Governor Schwarzenegger signed on September 27, 2006 to further the goals of Executive Order S-3-05. AB 32 states:

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

AB 32 represents the first enforceable statewide program to limit GHG emissions from all major industries with penalties for noncompliance. The foremost objective of California Air Resources Board (CARB), tasked with implementing AB 32, is to adopt regulations that require the reporting and verification of statewide GHGs. The initial State goal is to limit GHG emissions to 1990 levels by 2020. In January 2008, a statewide cap for 2020 emissions based on 1990 levels was adopted. In June 2010, CARB prescribed GHG reduction goals to regional governments, including the Association of Monterey Bay Area Governments (AMBAG). These prescriptions are the regional benchmarks from which to track local reductions.

***Executive Order S-1-07 (2007)***

On January 18, 2007, California further solidified its dedication to reducing GHGs by setting a new Low Carbon Fuel Standard for transportation fuels sold within the state. The target of the Low Carbon Fuel Standard is to reduce the carbon intensity of California passenger vehicle fuels by at least 10 percent by 2020.

***Senate Bill 97 (2007)***

SB 97, enacted in 2007, amended the California Environmental Quality Act (CEQA 2012) statute to clearly establish that GHG emissions and effects of GHG emissions are subject to CEQA. It also directed the Governor's Office of Planning and Research (OPR) to develop CEQA Guidelines to address GHG emissions for approval by the California Natural Resources Agency. The Natural Resources Agency adopted the amendments in January 2010, which went into effect in March 2010. The amendments do not identify a threshold of significance for GHG emissions, nor do they prescribe assessment methodologies or specific mitigation measures. The amendments encourage lead agencies to consider many factors in performing a CEQA analysis, but preserve the discretion granted by CEQA to lead agencies in making their own determinations based on substantial evidence. The amendments also encourage public agencies to make use of programmatic mitigation plans and programs when they perform individual project analyses.

***Executive Order S-13-08 (2008)***

Executive Order S-13-08 launched a major initiative for improving the state's adaptation to climate impacts from sea level rise, increased temperatures, shifting precipitation, and extreme weather events. It ordered a California Sea Level Rise Assessment Report to be conducted by the National Academy of Sciences, which was released in June 2012. It also ordered the development of a California Climate

Change Adaptation Strategy. The Strategy, published in December 2009, assesses the state's vulnerability to climate change impacts, and outlines possible solutions that can be implemented within and across State agencies to promote resiliency. The Strategy focuses on seven areas: public health, biodiversity and habitat, ocean and coastal resources, water management, agriculture, forestry, and transportation and energy infrastructure.

***California Ocean Protection Council Resolution***

California Ocean Protection Council (OPC) Resolution, adopted on March 11, 2011, requires the vulnerabilities associated with sea level rise to be considered for all projects or programs receiving funding from the State. The Resolution states: "Given the currently predicted effects of Climate Change on California's water resources, IRWM Plans should address adapting to changes in the amount, intensity, timing, quality and variability of runoff and recharge. Areas of the State that receive water imported from the Sacramento-San Joaquin River Delta, the area within the Delta, and areas served by coastal aquifers will also need to consider the effects of sea level rise on water supply conditions and identify suitable adaptation measures." The OPC resolution and sea level rise guidance can be found at the following link: http://www.opc.ca.gov/council-documents/.

## R.2 PREDICTED EFFECTS OF CLIMATE CHANGE IN CALIFORNIA

Climate change models predict changes in temperature, precipitation patterns, water availability, and sea levels, and these altered conditions can have severe impacts on natural and human systems in California (California EPA 2010). Sea levels have risen by as much as seven inches along the California coast over the last century, increasing erosion and pressure on the state's infrastructure, water supplies, and natural resources. The state has also seen increased average temperatures, more extreme hot days, fewer cold nights, a lengthening of the growing season, shifts in the water cycle with less winter precipitation falling as snow, and both snowmelt and rainwater running off sooner in the year (California Natural Resources Agency 2009). According to the California Department of Water Resources (DWR 2009a), more changes related to climate change can be expected by the year 2050 and on to the end of the century:

- California's mean temperature may rise 1.5°F to 5.0°F by 2050 and 3.5°F to 11°F by the end of the century.
- Average annual precipitation may show little change, but more intense wet and dry periods can be expected with more floods and more droughts.
- Flood peaks will become higher and natural spring/summer runoff will become lower.
- Global sea level projections suggest possible sea level rise of approximately 14 inches (36 cm) by 2050 and a high value of approximately 55 inches (140 cm) by 2100.[2]

In 2009, the Pacific Institute completed one of the first statewide evaluations of the vulnerability of California coastal infrastructure and communities to sea level rise. The study reports:

> *Rising sea levels will be among the most significant impacts of climate change to California. Sea level will rise as a result of thermal expansion of the oceans and an increase in ocean volume as land ice melts and runs off. Over the past century, sea level has risen nearly eight inches along the California coast and general circulation model scenarios suggest very substantial increases in sea level due to climate change over the coming century.* (Heberger et al. 2009)

[2] The State of California uses estimates of global sea level rise produced by Ramstorf 2007 and Cayan et al. 2008 for coastal adaptation planning purposes under Executive Order S-13-08.

The Pacific Institute study provides an analysis of coastal resources, human populations, infrastructure, and property that is at risk from projected sea level rise if no actions are taken. The study evaluates how the cumulative impacts of increased watershed flooding, sea level rise, and storm surge can impact coastal areas through increased flooding and coastal erosion.

The study evaluated and mapped areas of the California coast that are vulnerable to flooding with a 55-inch (1.4 meter) increase in sea level rise. Table R-1, below, shows the population vulnerable to flood and erosion from a 1.4-meter sea level rise along the Pacific coast in California, by county. Monterey and Santa Cruz counties were identified as the two counties most vulnerable to flood-related risks of sea level rise in terms of population, due to the vast low lying areas of the Pajaro and Salinas valleys.

**Table R-1: Population Vulnerable to Flood and Erosion from Sea Level Rise**

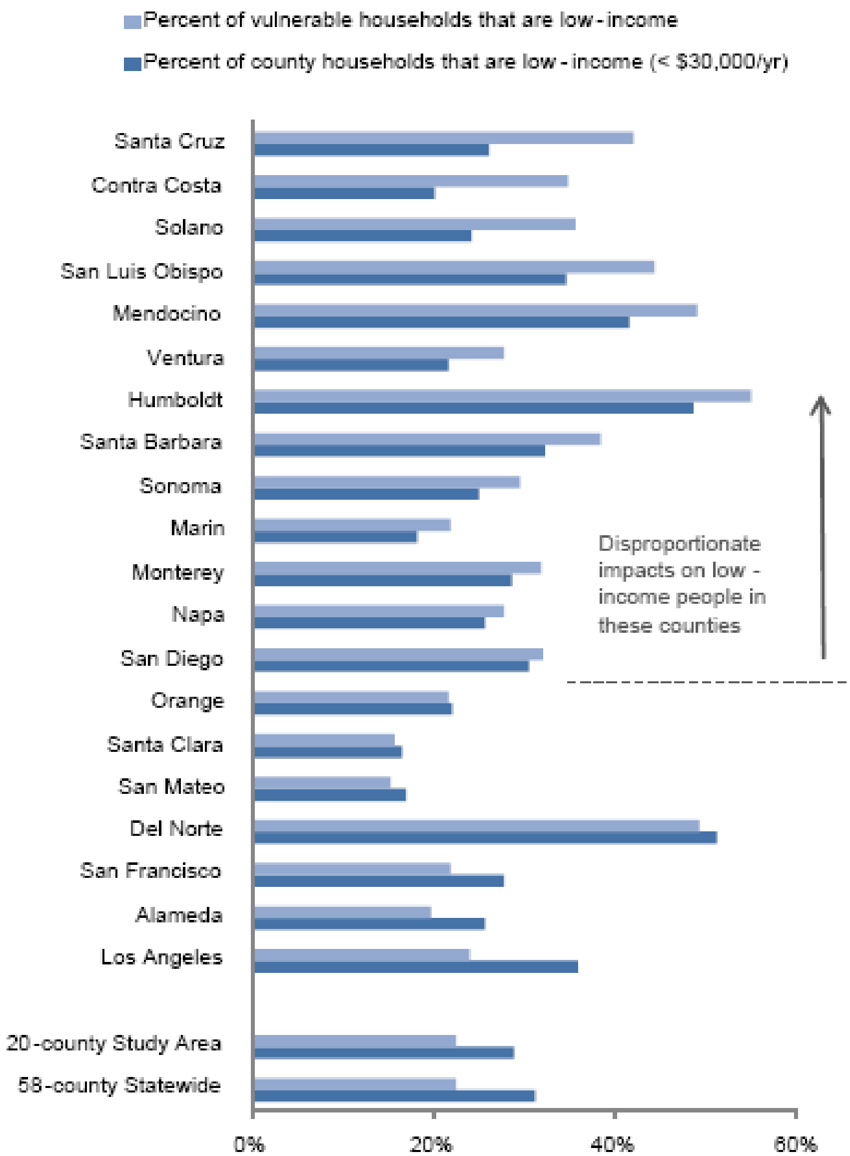
| County | Flood-related Risk | Erosion-related Risk |
|---|---|---|
| Del Norte | 2,600 | 620 |
| Humboldt | 7,800 | 580 |
| Marin | 630 | 570 |
| Mendocino | 650 | 930 |
| Monterey | 14,000 | 820 |
| San Francisco | 6,500 | 1,200 |
| San Luis Obispo | 1,300 | 1,100 |
| San Mateo | 5,900 | 2,900 |
| Santa Barbara | 6,700 | 2,100 |
| Santa Cruz | 16,000 | 2,600 |
| Sonoma | 700 | 300 |
| **Total** | **63,000** | **14,000** |

Source: Pacific Institute (Heberger et al. 2009)

The Pacific Institute study notes that a 1.4-meter sea level rise will put a wide range of critical infrastructure, such as roads, hospitals, schools, emergency facilities, wastewater treatment plants, and power plants, at risk. Throughout California, $100 billion (in year 2000 dollars) in property is at risk of coastal flooding. To help protect against the impacts of sea level rise, the study identified the need to construct, raise, or repair 53 miles of levees and seawalls in Monterey County. The cost to construct the new sea walls was estimated at $650 million, or $12 million dollars a mile (note that this estimate does not include the options of adaptation or retreat). A risk assessment and resource protection prioritization process will need to be completed to identify which resources and infrastructure are most in need of protection.

The Pacific Institute study also evaluated the potential impacts of sea level rise on disadvantaged communities (DACs). Monterey County, along with 12 other coastal counties, is expected to see a disproportionate impact of sea level rise on DACs (see Figure R-2). In Monterey County, this impact will be seen particularly within the community of Castroville and in the Salinas Valley.

**Figure R-2: Impact of Sea Level Rise on DACs**




Source: Pacific Institute (Heberger et al. 2009). Used by permission.

The changes in sea levels, temperature, and precipitation from global climate change that are anticipated to occur with climate change, as described above, will affect California's public health, habitats, ocean and coastal resources, water supplies, agriculture, forestry, and energy use (California EPA 2010), and result in increased droughts and flooding. Climate change could also have adverse effects on water quality, which would in turn affect the beneficial uses (habitat, water supply, etc.) of surface water bodies and groundwater. Changes in precipitation could result in increased sedimentation, higher concentrations of pollutants, higher dissolved oxygen levels, increased temperatures, and an increase in the amount of runoff constituents reaching surface water bodies.

Climate change is also expected to have effects on diverse types of ecosystems, from alpine to deep sea habitat. As temperatures and precipitation change, seasonal shifts in vegetation will occur; this could affect the distribution of associated flora and fauna species. As the range of species shifts, habitat fragmentation could occur, with acute impacts on the distribution of certain sensitive species. The IPCC states that “20 percent to 30 percent of species assessed may be at risk of extinction from climate change impacts within this century if global mean temperatures exceed 2°C to 3°C (3.6°F to 5.4°F) relative to pre-industrial levels” (IPCC 2007a). Shifts in existing biomes could also make ecosystems vulnerable to invasive species encroachment. Wildfires, which are an important control mechanism in many ecosystems, may become more severe and more frequent, making it difficult for native plant species to repeatedly re-germinate. In general terms, climate change is expected to put a number of stressors on ecosystems, with potentially catastrophic effects on biodiversity.

The IPCC modeled several possible emissions trajectories to determine what level of reductions would be needed worldwide to stabilize global temperatures and minimize climate change impacts. Regardless of the analytic method used, global average temperature and sea level rise were predicted to rise under all scenarios (ibid). For example, the IPCC predicted that the range of global mean temperature change from year 1990 to 2100, given different emissions reductions scenarios, could range from 1.1°C to 6.4°C (2.0°F to 11.5°F). In other words, there is evidence that emissions reductions can reduce the severity of climate change effects but cannot reverse them entirely.

## R.3 PREDICTED EFFECTS OF CLIMATE CHANGE IN THE GREATER MONTEREY COUNTY REGION

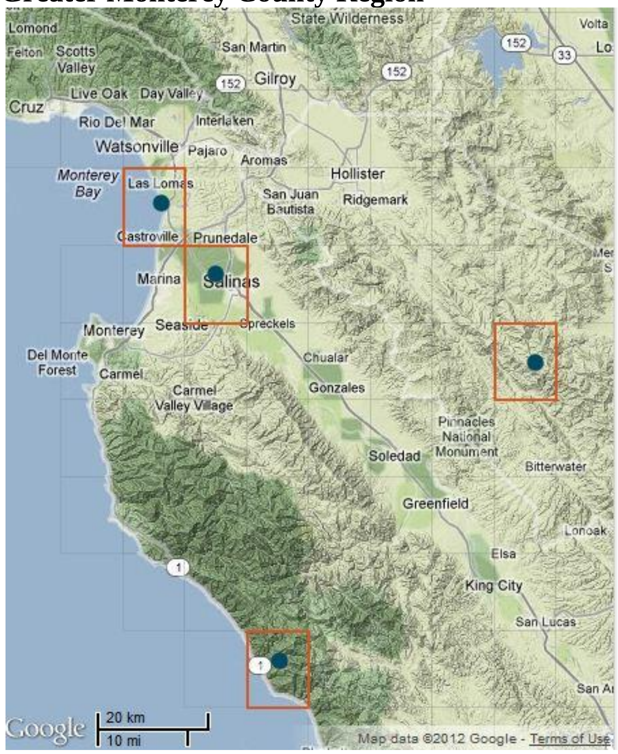
This section first takes a look at projected changes in climate variables, and then considers the impacts of climate change for the local region.

### R.3.1 Projected Changes in Climate Variables

Many climate models have been generated to predict changes in ocean and land temperature, rain frequency and intensity, coastal wave exposure, and sea level rise. Modeling using regional climate models has matured over the past decade to enable meaningful climate vulnerability assessment applications (Wang et al. 2004). California has created several web-based interfaces to help local and regional planners “downscale” climate models for local planning purposes. The Cal-Adapt website (http://cal-adapt.org/) provides a geographically based climate model interpretation tool that generates predictive changes to various climate variables using different IPCC GHG emissions projections. Specifically, emissions scenario A2 (High Emissions Scenario) coincides with a scenario in which no effort is taken to alter present practices, resulting in increasing rates of emissions. Emissions scenario B1 (Low Emissions Scenario) coincides with emission rates associated with global success at curbing emissions as prescribed within international climate treaties.

The Cal-Adapt tool was used to project changes in various climate variables that may affect water resources within the Greater Monterey County IRWM planning area. Four areas of the region were used to reflect different climate regimes: Coastal Monterey Bay, Coastal Big Sur Mountains, Inland Valley, and Inland Mountains (Figure R-3). Changes in climate variables are presented for the A2 emissions scenario as a worst-case prediction of potential vulnerabilities. Future analysis will be able to increase climate prediction evaluation for a select set of potential impacts based on this initial investigation.

**Figure R-3: Four Climate Regimes Modeled in the Greater Monterey County Region**




Source: Cal-Adapt (http://cal-adapt.org/)

**Temperature Changes**

Table R-2 below shows the projected difference in temperature between a baseline time period (1961-1990) and an end of century period (2070-2090) for the four climate regime areas selected for the Greater Monterey County IRWM planning region.

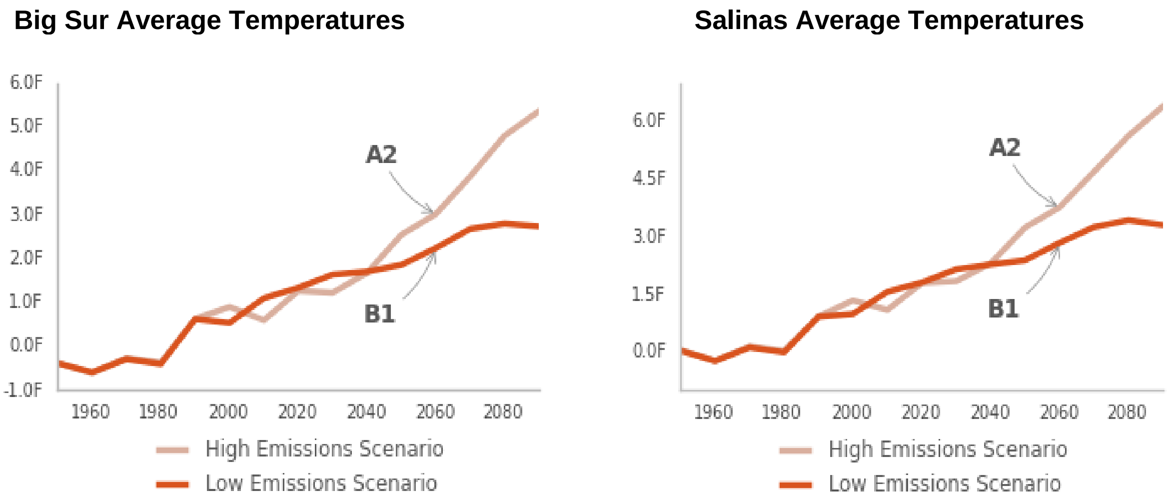
**Table R-2: Projected Increases in Average Temperature**

| Location | Low emission-B1 (°F) | Change in temp (°F) | High emission-A2 (°F) | Change in temp (°F) | Historical average (°F) |
|---|---|---|---|---|---|
| **Salinas** | 60.6 | 3.4 | 63 | 5.6 | 57.4 |
| **Moss Landing** | 60.4 | 3.2 | 62.7 | 5.5 | 57.2 |
| **Big Sur** | 54.3 | 2.8 | 56.2 | 4.7 | 51.5 |
| **Paicines (mountains)** | 57.7 | 3.3 | 59.9 | 5.5 | 54.4 |

Source: Cal-Adapt web tool (http://cal-adapt.org/)

Projected increases in average temperature are graphed for the Big Sur coast and the Salinas Valley in Figure R-4 below. Projected increases in temperature are similar through 2050 for both the A2 (High Emissions) and B1 (Low Emissions) scenarios. After 2050, temperature increases more rapidly using the high emissions rate scenario.

**Figure R-4: Projected Average Temperatures in Big Sur and Salinas**



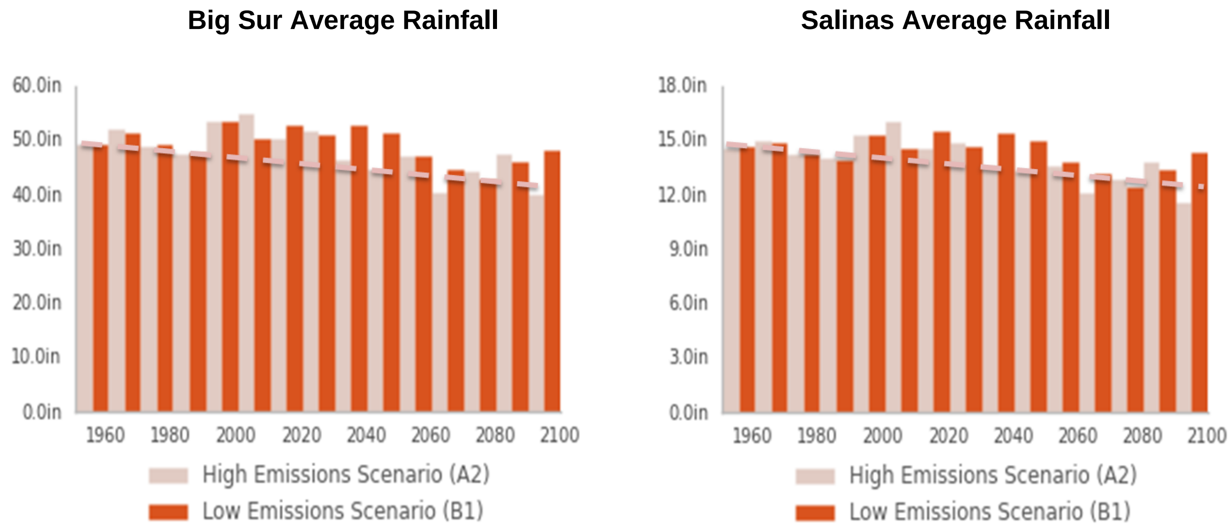

Source: Cal-Adapt web tool (http://cal-adapt.org/)

**Rainfall Changes**

The Cal-Adapt tool predicts that average rainfall will begin to decline throughout the Greater Monterey County region with projected decreases of approximately ten inches (20 percent) in the Big Sur area and approximately three inches in the Salinas Valley region (20 percent) by 2100 (High Emissions Scenario A2). Figure R-5 below represents the inter-decadal fluctuations in precipitation (integrating historic decadal fluctuations) and the long-term decline in total precipitation for the areas in question. Note, however, that while most climate change scientists agree that precipitation patterns will change, there is less consensus on the direction of the precipitation change, with some climate models suggesting decreases while others suggest increases.[3] According to DWR, average annual precipitation throughout the state may show little change, but more intense wet and dry periods can be expected with more floods and more droughts (DWR 2009a). The actual change in precipitation is more difficult to predict on the local level.

[3] As an example of variable predictions of precipitation impacts in California: A US Department of the Interior Bureau of Reclamation report (2011) predicts mean-annual precipitation in the Sacramento and San Joaquin basins will stay generally steady during the 21st century and will be quite variable over the next century, with the authors noting that there is significant disagreement among the climate projections regarding change in annual precipitation over the region. The 2009 California Climate Change Adaptation Strategy (California Natural Resources Agency 2009) notes that climate models for the state differ in determining where and how much rain and snowfall patterns will change under different emissions scenarios. However, while the precipitation modeling results vary more than the temperature projections, the authors point out that 11 out of 12 precipitation models run by the Scripps Institution of Oceanography for northern California suggest a small to significant (12-35 percent) overall decrease in precipitation levels by mid-century. Finally, a US Geological Survey report (USGS 2012), using five General Circulation Models (GCM) for two watershed basins in northern California, concludes that precipitation will follow cycles of wetter and drier decadal oscillations during the 21st century.

**Figure R-5: Projected Average Rainfall in Big Sur and Salinas**




Source: Cal-Adapt web tool (http://cal-adapt.org/). Note: dashed line represents the average decline in projected rainfall (using the high emissions scenario) when inter-decadal variability is omitted.

Other climate variables, including evapotranspiration (water loss in plants) and runoff rates from storms, will also increase over time. Average base flow levels in creeks are projected to decline.

**Sea Level Rise**

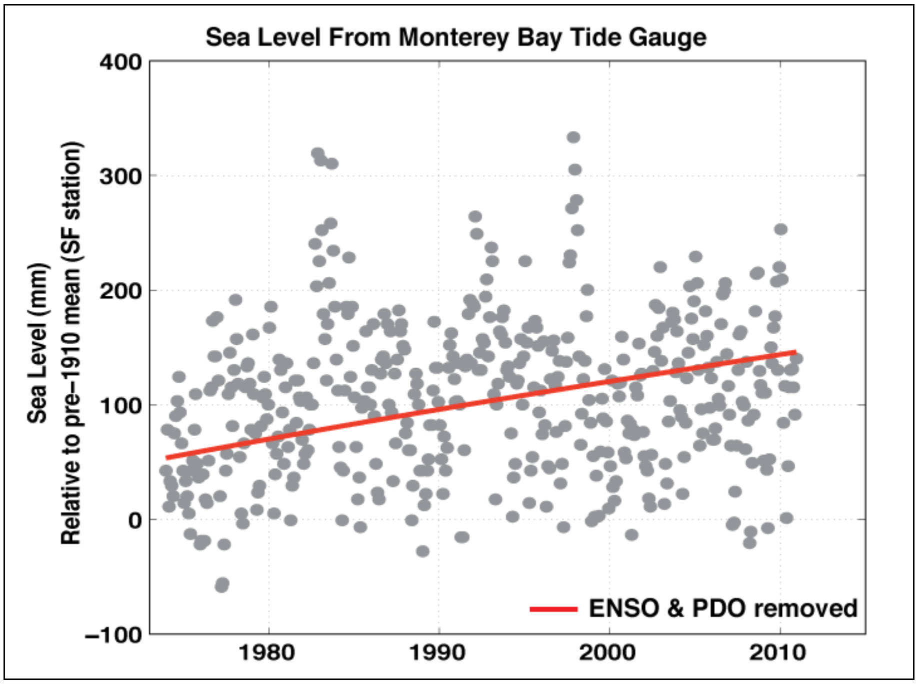
Sea level rise[4] is a complex and dynamic process ultimately controlled by levels of heat-trapping greenhouse gases in the atmosphere. Globally, sea level rise is driven by two primary factors—global ice melt and thermal expansion of seawater—but locally there are numerous processes that can alter the rate, extent, and duration of changes in sea level. As such, accurately predicting sea level over the coming centuries for specific locations is very challenging.

Sea level rose approximately seven inches (18 cm) over the past century (1900–2005) along most of the California coast (Cayan et al. 2008). The local tide gauge at Monterey dates back to 1973 (compared to the San Francisco gauge dating from 1855), but even during this short time period, a trend of sea level rise is evident at the rate of approximately 0.05 inches per year (Figure R-6). Due to local oceanographic conditions, sea level in central California has been relatively stable or even declining over the past several decades. However, when the regional climate patterns that drive local sea level trends shift, the Central Coast will very likely experience a rise in sea level that will correspond to, or may even exceed, the mean global rate of sea level rise (Largier et al. 2010; Ramp et al. 2009; and Bromirski et al. 2011).

Currently, the State of California is using estimates of global sea level rise produced by Rahmstorf (2007) and Cayan et al. (2008) for coastal adaptation planning purposes under Executive Order S-13-08. These projections suggest possible sea level rise of approximately 14 inches (36 cm) by 2050 and up to approximately 55 inches (140 cm) by 2100. However, recent evidence suggests these values may prove to be underestimates of the possible rise in global sea level.

[4] This section regarding sea level rise has been excerpted from the "Climate Change and Monterey Bay" website (http://www.climatechangemontereybay.org/impacts_main.shtml). Text prepared by Michael Fox, Center for Ocean Solutions. The references in this section are as cited on the "Climate Change and Monterey Bay" website.

**Figure R-6: Sea Level in Monterey Bay from 1976-2010**




Sea level from the Monterey Bay Tide Gauge. Monthly records of sea level from the Monterey Bay tide gauge are shown from 1976 to 2010. Monterey has experienced a consistent rise in sea level on the order of 2 - 3 mm/yr (0.07 - 0.1 in/yr) for the past 35 years. (Developed by Brock Woodson for the Preparing for the Future: Climate Change and the Monterey Bay Shoreline regional workshop; see http://centerforoceansolutions.org/preparingforthefuture. Data obtained from the Permanent Service for Mean Sea Level [PSMSL]. Used by permission.)

The anticipated consequences of sea level rise for the Monterey Bay region are serious and far-reaching, and are discussed in Section R.3.2 below, Predicted Impacts of Climate Change.

**Changes in Fog**

There is evidence to suggest that yearly coastal fog may be declining. A recent study by Todd Dawson from UC Berkeley and James Johnstone from the University of Washington shows that coastal fog in California has declined more than 30 percent over the past 60 years (Sanders 2010; Dayton 2011). With only 60 years of data, it is unclear whether the phenomenon is part of a natural cycle or the result of global climate change.[5] However, a change in coastal fog could have critical implications for the fate of certain ecosystems, in particular coastal redwoods and maritime chaparral, both of which are dependent on fog for their survival. A decline in coastal fog could also lead to increased water use and an increased demand on water supplies in the Greater Monterey County IRWM region.

California coastal fog is caused by the temperature differential between the cool ocean water and the warmer air. The Monterey Bay region is particularly foggy because of oceanic upwelling of the deep, cold waters of the Monterey submarine canyon. When the cold oceanic water meets the warmer air, the air chills and condenses to form fog. As noted above, one of the effects of global climate change is warmer ocean temperatures. The IPCC stated in a 2007 report, “observations since 1961 show that the average

[5] Note that the scientists are working to calibrate tree ring isotope data with actual coastal fog conditions in the past century, and will then be able extrapolate back for 1,000 years or more to estimate climate conditions.

temperature of the global ocean has increased to depths of at least 3000 meters" (IPCC, 2007b). Warmer ocean temperatures could mean less fog for coastal California.

Fog occurs primarily in the summer months, when there is little or no rainfall. Fog provides an important source of water for many coastal plant communities by providing soil drip; and some plants, including redwoods and 80 percent of their understory plants, can absorb fog directly through their leaves. Fog also acts to keep moisture in the ecosystem, preventing evaporation and maintaining cooler temperatures. A significant decline in fog could mean an uncertain future for many of the plant communities in the region, including local endemic plants that depend on fog for their survival (Dayton 2011).

The role that coastal fog plays in preventing evaporation and maintaining cooler temperatures also has important implications for water use and water supply in the Greater Monterey County region. A decline in coastal fog would change the local coastal climate, resulting in warmer temperatures and increased evaporation during the summer months. This in turn may lead to increased agricultural and landscape water use, putting additional demand on water supplies in the region.

### R.3.2 Predicted Impacts of Climate Change in the Greater Monterey County Region

Numerous tools are available to assist local water resource managers in evaluating the potential impacts of climate change on local infrastructure and populations. DWR provides a list of potential impacts to water resources associated with changes in climate variables. The State has also provided guidance on possible impacts to state infrastructure and resources due to changing climate variables. These resources were used to identify local impacts that are most likely to occur in the Greater Monterey County IRWM region, due to local changes in rainfall patterns, temperature increases, evapotranspiration, storm intensity and runoff rates, and urban and agricultural water use.

Table R-3 below represents a "broad brush" consideration of potential impacts to water resources associated with changes in climate variables, based on the State's guidance as applied to the Greater Monterey County region (adapted from Appendix B of *Climate Change Handbook for Regional Water Planning*). Following this list is a more detailed discussion of potential impacts of climate change in the Monterey Bay region, as presented at a December 2011 regional workshop called "Preparing for the Future: Climate Change and the Monterey Bay Shoreline."

**Table R-3: Potential Impacts to Water Resources in the Greater Monterey County Region**

| |
|---|
| *Water Supply and Demand*<br>▪ Agricultural water use is expected to increase to offset higher temperatures and evapotranspiration.<br>▪ Rangelands are expected to be drier.<br>▪ Domestic landscaping water needs will be higher.<br>▪ Sea level rise and higher groundwater extraction will lead to increased rates of saltwater intrusion.<br>▪ Droughts will be more frequent and severe. |
| *Water Quality*<br>▪ Lower seasonal surface flows will lead to higher pollutant concentrations.<br>▪ Changes in storm intensity will increase sediment loading in many systems.<br>▪ Channel stability will be impacted from higher storm flows causing additional turbidity.<br>▪ Sea level rise will impact current estuary brackish water interface towards more marine systems. |
| *Flooding*<br>▪ Regional river levees will provide less protection during higher storm flow events.<br>▪ Natural creeks and managed conveyance will see higher flow rates leading to increased erosion and flooding.<br>▪ Coastal levees and control structures will be undersized to manage the combined influences of higher river flows and sea level rise. |
| *Aquatic Ecosystem Vulnerabilities*<br>▪ Migration patterns and species distribution will change.<br>▪ Invasive species populations will expand.<br>▪ Coastal wetland systems are likely to be inundated with increasing frequency, leading to the dieback of tidal marshes (Philip Williams & Associates 2008b) and the salinization of fresh and brackish marshes.<br>▪ Changes in hydrograph (driven by rain pattern changes) will cause increased erosion and habitat loss in creeks and rivers.<br>▪ Some locally unique species and communities such as maritime chaparral, coastal prairie, coastal redwoods and giant kelp are susceptible to changes in certain locally favorable climate variables; for example, redwood forest ecosystems and coastal chaparral species are dependent on fog, and productive kelp forests tend to be associated with areas of significant oceanographic upwelling. As conditions change, these ecosystems and species may face an uncertain future (see Dayton 2011). |
| *Hydropower and Reservoir Storage*<br>▪ Changes in rainfall patterns may be problematic for timing of release from reservoirs.<br>▪ More intense rainfall and increased risk of fires in watershed lands can lead to increased sediment loading to reservoirs. |

***Preparing for the Future: Climate Change and the Monterey Bay Shoreline***

On December 6, 2011, the Monterey Bay National Marine Sanctuary (MBNMS) and Center for Ocean Solutions (COS) convened regional decision makers at a one-day workshop titled "Preparing for the Future: Climate Change and the Monterey Bay Shoreline." The event was the first Monterey Bay region-wide gathering on climate change adaptation, intended to facilitate a discussion on how to best prepare coastal communities in the Monterey Bay region to adapt to the impacts of climate change. More than 90 people attended from cities and municipalities in Santa Cruz and Monterey Counties, representing city and county staff, state and federal governments, research institutions and nonprofit organizations.

Presenters at the workshop focused on impacts of concern for the Monterey Bay region, which include: increased coastal erosion, coastal inundation, storm and wave damage, and saltwater intrusion. Collectively, these impacts will threaten infrastructure, development, marine and coastal ecosystems, and the general welfare of the communities around Monterey Bay. Monterey Bay has variable coastal geology, and as a result, different regions will experience different types and magnitudes of impacts. For example, portions of the sandy beaches and dunes of southern Monterey Bay are currently eroding at some of the highest rates in California, while the low-lying land and large flood plains in the central portion of the Bay make those areas particularly susceptible to inundation (Abeles et al. 2012).

The following provides information presented at the workshop regarding the anticipated impacts of climate change specifically for the Monterey Bay shoreline area. Note that almost all of the text in this section has been excerpted from one of two sources: 1) the "Climate Change and Monterey Bay" website, http://www.climatechangemontereybay.org/; and 2) the workshop Summary Report (Abeles et al. 2012), which is available at: http://centerforoceansolutions.com/preparingforthefuture.

**Coastal Erosion**

Existing levels of coastal erosion in the Monterey Bay region cause significant threats to critical infrastructure, property, and natural habitats.[6] Coastal erosion will increase as global sea levels continue to rise. Higher sea level will allow waves and tides to travel farther inland, exposing beaches, cliffs, and coastal dunes to more persistent erosional forces (Storlazzi and Griggs 2000). Erosion is not a new issue in California, but rising sea levels threaten to increase the severity and frequency of erosion damage to coastal infrastructure and property. Statewide, a 4.6-foot (1.4 m) rise in sea level has the potential to erode approximately 41 square miles (68 km2) of coastline by the end of the century (Heberger et al. 2009).

The southern portion of Monterey Bay is eroding more rapidly than any other region in the state, with coastal dunes between the Salinas River mouth and Wharf II in Monterey eroding at rates between 1.0 and 6.0 feet per year (0.3-1.8 m/yr) (Heberger et al. 2009; Brew et al. 2011; and Hapke et al. 2009). Even without consideration of accelerated sea level rates, eight oceanfront facilities in southern Monterey Bay are at high risk in the next 50 years and will require mitigation measures to prevent their loss (Philip Williams & Associates 2008a). One statewide study by the California Energy Commission, *Impacts of Sea Level Rise on the California Coast*, found that in Monterey County a total of approximately 4.4 square miles (7 $km^2$) of coastline is susceptible to erosion, and the maximum distances coastal dunes and sea cliffs are expected to retreat in this region are approximately 1,300 and 720 feet (400 m and 200 m), respectively (Heberger et al. 2009). Loss of this land threatens to place roughly 820 people in Monterey County at risk of losing their homes (ibid.). In addition to the loss of the protective service, losing these coastal dunes also means the loss of habitat for coastal species.

Coastal erosion will have long-lasting impacts on the Monterey Bay region's transportation infrastructure, threatening over 50 miles (~83 km) of highway, roads, and rail throughout the region including Highway 1 (ibid.). Important public infrastructure is also at risk of erosion. One example is the Monterey Interceptor pipeline that carries raw sewage from the Monterey Peninsula to the treatment plant located north of the city of Marina. Portions of this critical piece of infrastructure run directly beneath the beach, and if undermined, could result in a significant threat to marine resources and public welfare and safety. Other threatened structures include beachfront hotels, condominiums, private residences, and other wastewater pumping stations associated with the Monterey Interceptor pipeline. Given the current rates of

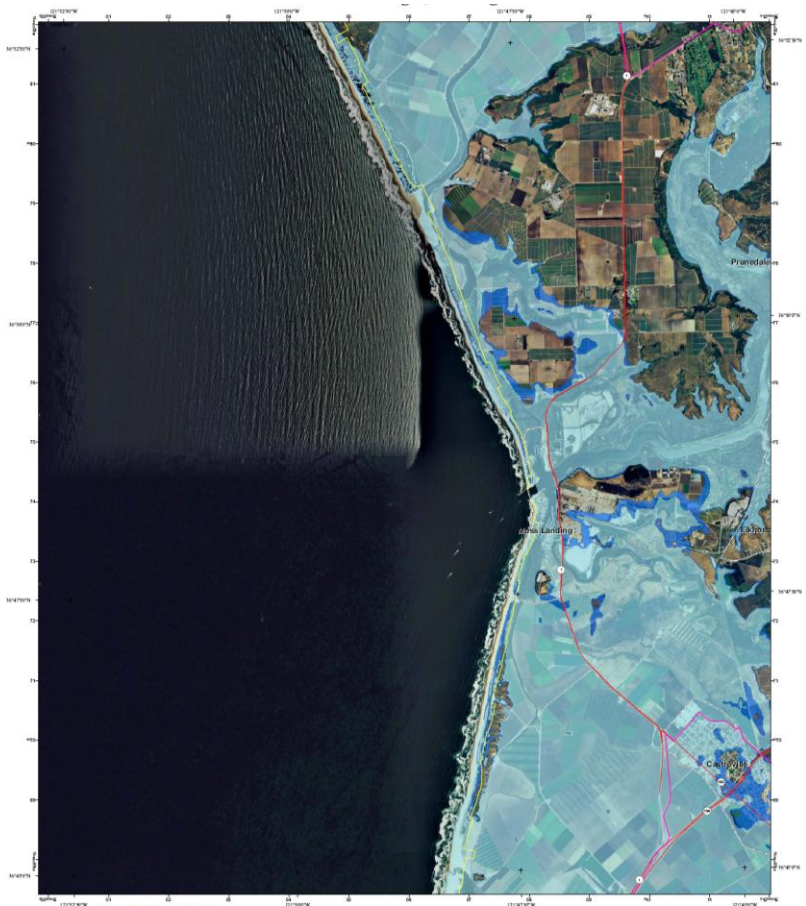
[6] This section on coastal erosion has been excerpted from the "Climate Change and Monterey Bay" website: http://www.climatechangemontereybay.org/impacts_erosion.shtml. Text prepared by Michael Fox, COS. All references included in this section are cited on the website.

erosion, this sewage pipeline faces possible risk of exposure in the next 30 to 50 years (Brew et al. 2011), highlighting the importance of strategic long-term planning efforts.

**Coastal Inundation**

Coastal inundation occurs when normally dry land becomes covered by water and it is one of the most costly and damaging impacts associated with sea level rise.[7] Low-lying coastal areas of the Monterey Bay region will be exposed to a greater risk of major flooding events, and storm surge, high tides, and waves will travel farther inland (Heberger et al. 2009). Elevated sea levels combined with increases in winter storm intensity and wave heights will make coastal inundation a more serious risk (Storlazzi and Wingfield 2005; and Wingfield and Storlazzi 2005).

**Figure R-7: Predicted Flooding in Moss Landing Area due to Sea Level Rise and Increased Winter River Flows**



Map depicting where increased inundation will occur within the Moss Landing area without adaptation from a 1.4m sea level rise. The light blue is the current 500-year flood zone as defined by the Federal Emergency Management Agency. Source: Heberger 2009 (Pacific Institute). Used by permission.

Given the large impact zone associated with coastal inundation, a significant portion of transportation infrastructure is at risk. Highways, roads, and railways in Monterey County are susceptible to coastal

[7] This section on coastal inundation (except for last two paragraphs) has been excerpted from the "Climate Change and Monterey Bay" website: http://www.climatechangemontereybay.org/impacts_inundation.shtml. Text prepared by Michael Fox, COS. All references included in this section are cited on the website.

inundation, and flooding may impact several power generating facilities (Heberger et al. 2009). The low-lying coastal location of many agricultural properties in this region increases the likelihood of significant loss of agricultural land due to storm-induced flooding and salinization with increasing sea level and long-term inundation. Loss of agricultural production in the region will have lasting consequences for the largest sector of the regional economy.

In conjunction with coastal inundation, coastal water quality will likely decline as storm-induced flood waters recede, drawing debris, fertilizers, and other contaminants into the bay. This increased runoff has the potential to increase the frequency and severity of harmful algal blooms (HABs) in the area posing a serious threat to local fisheries and marine mammal populations (Largier et al. 2010).

Coastal inundation also poses a risk to local wetlands. The impact of sea level rise on wetlands is significant for the Greater Monterey County area, since the region contains several important wetland systems. If the rate of sea level rise exceeds the rate of wetland accretion, or if wetlands cannot transgress (migrate up and inland) large tracts of critically important habitat, such as Elkhorn Slough, will become permanently submerged (Heberger 2009; Largier 2010). If these wetland systems become submerged, their ability to provide crucial services such as nursery habitat, wave protection, and nutrient and sediment retention will be greatly diminished. There are several other wetland systems that interact with the main Elkhorn system, including the Moro Cojo and Bennett Sloughs and the Old Salinas River channel. All of these systems' tidal interactions are muted due to culverts and tide gates. Sea level rise will pose significant threats to these systems as well, but those interactions are less well understood.

Monterey County also hosts about 30 coastal river and creek mouth lagoon systems that provide a diverse set of environmental services and span the entire of the IRWM planning region. The cumulative impacts of increased rain intensity and flows within coastal watersheds along with increased sea levels and storm wave impacts pose unique threats to these valuable wetland resources. Regional partners have begun to evaluate the potential impacts to these systems, but studies are incomplete and more research is needed.

**Seawater Intrusion**

Seawater intrusion is caused by two primary processes: overdrafts of coastal wells and sea level rise. As described in the Region Description of this Plan, coastal groundwater basins in the region have been experiencing overdraft for many years. It is estimated that the Salinas Valley Groundwater Basin has an average annual non-drought overdraft of approximately 50,000 acre feet (AF) (Cal Water 2010a), though during the last drought the annual overdraft was estimated at 150,000–300,000 acre-feet/year (AFY) (Cal Water 2010b). As a result of this consistent overdraft, groundwater levels in the Salinas Valley Groundwater Basin have dropped below sea level, allowing seawater to intrude from Monterey Bay into aquifers located 180 and 400 feet below ground surface. The East Side and Pressure Subareas of the Salinas Valley Groundwater Basin are most impacted by overdraft (MCWRA 1997). Because of the hydrologic continuity between the ocean and the aquifers of the Pressure Area, seawater has been intruding into these aquifers at a rate of approximately 28,800 AFY (Cal Water 2010b).

In the mid-1990s, due to seawater intrusion, the Monterey County Water Resources Agency (MCWRA) constructed a water delivery system known as the Castroville Seawater Intrusion Project (CSIP), aimed at providing recycled water to agricultural growers within the seawater intrusion front area. These growers use the recycled water in lieu of pumping groundwater. Since 1998, recycled water deliveries have ranged from approximately 7,500-14,000 AFY. As a result of the CSIP, the seawater intrusion front has slowed, but has not been halted (ibid.). More recently, MCWRA developed the Salinas Valley Water Project as a means to increase the availability of recycled water, thereby further reducing agricultural pumping from intruded Pressure Subarea Aquifers.

While basin overdraft conditions are expected to improve by the year 2030 due to these and other efforts, recent groundwater modeling (from the Salinas Valley Integrated Ground and Surface Water Model, or SVIGSM) predicts seawater intrusion to continue to worsen, though at a decreased rate. The SVIGSM modeling did not take into account, however, expected sea level rise due to climate change. The problem of seawater intrusion is expected to be exacerbated significantly by sea level rise. Groundwater contaminated by saltwater is not suitable for agricultural use or for drinking water without treatment.

**Coastal Storms and Waves**

Seasonal patterns of storms and wave intensity are the primary driving forces behind coastal erosion along the California coast.[8] While a natural process that shape shorelines and beaches, erosional forces become a hazard when they interact with permanent structures that rely on a stable shoreline. The impacts of storm and wave damage are episodic and have the greatest severity when large storms coincide with high tide events. Despite the gradual day-to-day erosion experienced along the coast, it is the large, episodic erosional events that pose the greatest threat to the Monterey Bay shoreline. Given the recent evidence that suggests storm and wave intensity is likely to increase in this region, these large, episodic erosional events may occur more frequently. Protecting and restoring natural systems to take advantage of their protective services can increase resilience to these coastal impacts. Protecting and restoring these systems will likely provide additional benefits such as improved water quality and increased nursery habitat and recreation areas.

**Simulation of Climate Change in the Santa Cruz Mountains**

A regional study was completed by the US Geological Survey (Flint and Flint 2012), on how changing climate variables lead to a change in potential evapotranspiration, recharge, runoff, and climatic water deficit within the Santa Cruz Mountains. Hydrologic models predicted reduced early and late wet season runoff and summers are projected to be longer and drier in the future than in the past regardless of precipitation trends. While water supply could be subject to increased variability (that is, reduced reliability) due to greater variability in precipitation, water demand is likely to steadily increase because of increased evapotranspiration rates and climatic water deficit during the extended summers. This analysis identifies the areas in the landscape that are the most resilient or vulnerable to projected changes and implies greater water demand will occur to maintain current agricultural resources or land cover. Fine-scale modeling identifies areas possibly more resilient to climatic changes in contrast to locations where vegetation is currently living on the edge of its present-day bioclimatic distribution and, therefore, is more likely to perish or shift to other dominant species under future warming.

## R.4 EVALUATING THE ADAPTABILITY OF WATER MANAGEMENT SYSTEMS IN THE REGION TO CLIMATE CHANGE

The Integrated Regional Water Management Planning Act, CWC §10541(e)(10), states that IRWM plans must include an evaluation of the adaptability to climate change of water management systems in the region.

As described in the Region Description chapter of this IRWM Plan, stakeholders in the Greater Monterey County IRWM region work to address a number of critical and sometimes conflicting water issues. The county has made great strides in addressing many of these issues, but challenges remain. Essentially, whatever challenges exist currently for water managers in the Greater Monterey County IRWM region will be greatly exacerbated—and augmented—by the impacts of climate change. The RWMG has conducted an initial climate vulnerability analysis and risk assessment to help water resource managers evaluate these risks and to consider potential adaptation measures.

[8] This section on coastal storms and waves has been excerpted from the “Climate Change and Monterey Bay” website: http://www.climatechangemontereybay.org/impacts_storms.shtml. Text prepared by Michael Fox, COS.

### R.4.1 Initial Climate Risk Analysis

The State and other climate partners have provided numerous tools and several comprehensive guidance documents to evaluate the vulnerabilities of human and natural systems in the face of climate change variables described above. The RWMG has used a combination of tools to identify priority resources that face the greatest threat from the impacts of climate change. Those impacts were prioritized based on their likelihood and the consequence that those impacts pose on life, property, public resources, and the natural environment of the Greater Monterey County region.

Key documents used for this climate risk assessment include the State guidance *Climate Change Handbook for Regional Water Planning* (US EPA Region 9 and DWR 2011) and the guidebook *Preparing for Climate Change* (Snover et al. 2007). Both documents outline a process for defining vulnerable infrastructure, land uses, and habitats, for defining the sensitivity of those resources to changes in climate conditions, and evaluating the risk of impacts to those resources.

The RWMG used several tools to identify resources that are sensitive to changes in climate variables. The website for the International Council for Local Environmental Initiatives (ICLEI) – Local Governments for Sustainability provides an online tool to identify important resources (human and natural) that are susceptible to climate change, and the *Climate Change Handbook* provides a useful checklist for identifying potential water resource specific vulnerabilities. Below is a listing of the vulnerabilities defined in the *Climate Change Handbook*, as applicable to the Greater Monterey County IRWM planning region:

**Water Demand**

- Major industries require cooling/process water that could be impacted by changes in rainfall and sea level rise:
  - the Moss Landing Electric Power Plant in particular relies on water from the Moss Landing harbor;
  - agro-business relies on water for processing leafy green produce within the Salinas Valley.
- Water use varies more than 50 percent seasonally because agricultural irrigation needs vary significantly through the planting season.
- Some crops are climate sensitive to changes in daily high temperatures, including leafy greens. Vineyards are also vulnerable to changes in temperature.
- Groundwater supplies in the region lack resiliency in droughts because groundwater supplies are already overdrafted.
- Water use cannot be curtailed quickly because agriculture resource needs are extensive.
- Some stream flows are insufficient to support anadromous fish in many coastal streams within Big Sur.

**Water Supply**

- The Greater Monterey County region relies on coastal aquifers and suffers from saltwater intrusion.
- The Greater Monterey County region has significant invasive species issues that reduce water conveyance and water supply in local streams and rivers.

**Water Quality**

- Increased wildfires are a risk in mountains surrounding many of our reservoirs and creeks that supply water.
- The Greater Monterey County region relies on surface water supplies that are impacted by eutrophication, and that could be exacerbated by climate change.

- Many beneficial uses cannot be met currently.
- Both increased water temperatures and increased fog are associated with poor estuarine water quality.[9]

**Sea Level Rise**

- Coastal erosion is a significant issue in the Greater Monterey County region.
- Numerous coastal structures and levees are at risk from sea level rise.
- The region includes significant infrastructure and other assets, including water treatment facilities, water control structures, a state highway, the major north-south coastal rail road, and a marina, and thousands of acres of prime agricultural land that are located within six feet of the current high tide line, and therefore are most vulnerable to sea level rise.
- There are significant low-lying coastal habitats in the region including estuaries, dunes, coastal lagoons and brackish water marshes that play an important role in water quality.
- There are substantial areas that flood during storm surge events.
- Land subsidence exists in coastal areas, making estuarine wetland management difficult and sensitive to sea level rise.
- Tidal records suggest ocean levels in the Monterey Bay have been increasing by 1.34 mm/yr over the past few decades.

**Flooding**

- Critical infrastructure lies within the 200-year flood plain.
- Critical flood control infrastructure is old and undersized.
- Rising sea level will increase the extent of river flooding.
- Flood control structures of the Salinas Valley have been insufficient in the past (1995 and 1998) to contain flooding.
- Wildfires are a major concern for flooding in coastal and inland mountain ranges.

**Ecosystem and Habitat Vulnerabilities**

- Our region has coastal aquatic systems that are vulnerable to erosion and sedimentation.
- Numerous threatened and endangered species exist in the region.
- The region relies on significant aquatic recreational opportunities along the coast, beaches, and the Moss Landing harbor and Elkhorn Slough.
- Water quality and quantity concerns affect a number of the region’s creeks and rivers.
- The region hosts a vast network of coastal estuaries, lagoons, and river mouths as well as beaches and dune complexes that would be affected by changes in storm intensity.
- The region hosts a number of habitats that are particularly vulnerable to climate change, including estuaries, dunes, coastal prairie, maritime chaparral, freshwater marshes, brackish marshes, and redwood forests.
- There is considerable habitat fragmentation in the region that restricts species migration, and fragmentation may continue if policies are not developed to minimize such actions.

**Hydropower**

- Monterey County generates hydroelectric power at the Nacimiento Reservoir, which could be impacted by increased watershed erosion from changes in rainfall and fire intensity.
- Energy use is expected to increase in the region, and hydroelectric power has been increased recently.

[9] Personal communication from Ken Johnson (Marine Chemist, Monterey Bay Aquarium Research Institute) to Bryan Largay, Elkhorn Slough National Estuarine Research Reserve, January 2, 2009.

### R.4.2 Risk Assessment

In 2011, the City of Santa Cruz completed the first Climate Vulnerability and Risk Assessment in the Monterey Bay Area (see Atchison 2011). The City used the guidance of the *Preparing for Climate Change* document (Snover et al. 2007) and the Excel spreadsheet tools provided by ICLEI, including the Excel spreadsheet decision-making matrix to complete a vulnerability and risk assessment. The results of the vulnerability and risk assessments led to a resiliency analysis and adaptation strategy (Atchison 2011). A vulnerability analysis for the Greater Monterey County IRWM planning region will help the RWMG to select priority planning areas based on the region's potential impacts due to climate change and the associated risks to human health, infrastructure, the economy, and environment. The Greater Monterey County RWMG conducted this preliminary vulnerability analysis for the region, following the guidance provided by ICLEI and the State and as demonstrated by the City of Santa Cruz. Below is a description of that process and the assumptions that went into our analysis.

Note that the results of the vulnerability analysis are considered to be preliminary only; the analysis itself will be refined as more tools and more information become available. Information provided in this chapter has been reviewed and vetted at length by a Climate Task Force comprised of local scientists, land use managers, water resource managers, and coastal policy experts before the chapter was submitted for inclusion within this Plan. Participating entities on the Climate Task Force include: Central Coast Wetlands Group at Moss Landing Marine Laboratories, Stanford University Center for Ocean Solutions, Monterey Bay National Marine Sanctuary, Santa Cruz County, Association of Monterey Bay Area Governments, Monterey County Planning, California Water Company, Monterey County Water Resources Agency, Stanford University Natural Capital Project, California Department of Water Resources, Santa Cruz County Resource Conservation District, and The Nature Conservancy.

Climate preparedness planning relies on the evaluation and prioritization of risks. Risk is determined based on the probability that a certain impact will occur (*likelihood*) and the significance of that impact (*consequence*) on life, land uses, water resources, the economy, and the environment. The equation is: *Risk = Consequences x Likelihood.* Since no region has sufficient resources to address all potential impacts of climate change simultaneously, this prioritization process is necessary to address impacts that are most likely and that will result in the greatest detriment to life, the economy, and infrastructure (*consequence*).

#### R.4.2.a Likelihood

The probability that a specific impact will occur, defined within the ICLEI workbook as likelihood, is estimated based on the increased chance, or periodicity, that a certain event will occur. Table R-4 illustrates how the combined factors of risk and likelihood relate to the determination of priority planning areas. Table R-5 illustrates the "Likelihood Rating" of impacts based on the chance of an infrequent impact occurring more often ("recurrent risk") and the chance that a previously unrealized impact could occur ("single event").

**Table R-4: Risk Variables**

| | Low Likelihood | Medium Likelihood | High Likelihood |
|---|---|---|---|
| **High to Extreme Risk** | May be priority planning areas | Should be priority planning areas | Should be priority planning areas |
| **Low to Medium Risk** | Are unlikely to be priority planning areas | May be priority planning areas | Likely to be priority planning areas |

**Table R-5: Probability Variables**

| Likelihood Rating | Recurrent Risks | Single Event |
|---|---|---|
| **Almost Certain (5)** | Could occur several times per year | More likely than not - probability greater than 50% |
| **Likely (4)** | May arise about once per year | As likely as not - 50/50 chance |
| **Possible (3)** | May arise once in 10 years | Less likely than not but still appreciable - probability less than 50% but still notable |
| **Unlikely (2)** | May arise once in 10 years to 25 years | Unlikely but not negligible - probability low but noticeably greater than zero |
| **Rare (1)** | Unlikely during the next 25 years | Negligible - probability very small, close to zero |

### R.4.2.b Consequence

The consequence of a specific climate change impact occurring was evaluated individually for five different social, economic, and environmental factors, including specifically:

- Public safety
- Local economy and growth
- Community and lifestyle
- Environment and sustainability
- Public administration

The cumulative consequence from the combined impacts to specific social, economic, and environmental factors was then derived. For example, the consequences of failing to address sea level rise will depend on the potential impacts of that future sea level rise on the five factors listed above, combined. The consequence for each factor was estimated from little or no consequence (0) to serious devastation to infrastructure or significant economic or environmental impacts or loss of life (5).

### R.4.2.c Risk

The amount of risk involved from a climate change impact depends on both the likelihood and severity of the consequences that may result from that impact. Using the example of sea level rise, risk can be mitigated by reducing the consequence of the flooding or the possibility that flooding will occur at a given ocean height. Risk was determined for the Greater Monterey County region based on the consequences that are expected to arise from any particular impact occurring within the region. Consequences were evaluated for human wellbeing, economic stability, environmental health, and the ability of municipalities to respond. The Climate Impact Risk Analysis results, shown in Table R-6 below, defines the risk associated with each likely impact. Those that are most probable and devastating have been placed in yellow and pink boxes, representing higher likelihood and higher consequences.

Note that the results of these analyses are considered by the RWMG to be preliminary only. The RWMG will further evaluate the assessment results and – with input from the Climate Task Force – will adjust and reprioritize impacts and resulting actions as additional data are made available. It is also important to note that the risk assessment evaluates the likelihood and consequence of a specific environmental condition occurring and that this analysis does not factor in potential inaccuracies in the projected rate of environmental change (e.g., sea level rise) within a given timeframe. Therefore, agencies must consider and balance the relative risks and costs associated with under- and/or overestimating sea level rise and other environmental changes in making decisions.

**Table R-6: Climate Impact Risk Analysis**

| | Low Likelihood (3) | Medium Likelihood (4) | High Likelihood (5) |
|---|---|---|---|
| **Low Consequence (8-12)** | Lower seasonal surface flows can lead to higher pollutant concentrations<br>State recommendations suggest no new critical facilities be built within the 200-year floodplain (DWR 2008, DWR 2009b, CNRA 2009)<br>Migration patterns and species distribution will change<br>Invasive species populations will expand<br>Some locally unique species such as coastal redwoods and giant kelp are susceptible to changes in certain locally favorable climate variables (fog duration, coastal upwelling)<br>Higher rainfall and increased risk of fires in watershed lands can lead to increased sediment loading to reservoirs | Rangelands are expected to be drier<br>Changes in storm intensity will increase sediment loading in many systems<br>Channel stability will be impacted from higher storm flows causing additional turbidity<br>Coastal wetland systems are especially vulnerable to the combined influences of climate change<br>Changes in rainfall patterns may be problematic for timing of releases from reservoirs | Domestic landscaping water needs will be higher |
| **Medium Consequence (13-16)** | | Local rainfall is estimated to be reduced by 3-10 inches<br>Droughts will be more frequent and severe<br>Sea level rise will impact current estuary brackish water interface towards more marine systems<br>Natural creeks throughout the region and managed conveyance within the Salinas Valley will see higher flow rates leading to increased erosion and flooding | Agricultural water use is expected to increase to offset higher temperatures and evapotranspiration<br>Sea level rise and higher groundwater extraction will lead to increased rates of saltwater intrusion |
| **High to Extreme Consequence (17-20)** | | Regional levees will provide less protection during higher storm flow events | Coastal levees and control structures will be undersized to manage the combined influences of higher flow events and sea level rise |

### R.4.2.d Environmental Consequence of Climate Impacts

During the initial review of the climate risk evaluation, the Climate Task Force recognized that impacts that lead to significant environmental consequence, but that do not lead directly to impacts to human life or the economic use of lands, were not identified as high priority (in Table R-6 above). Because the Greater Monterey County IRWM Plan and the Climate Task Force members recognize the inherent value of natural habitats, an additional risk assessment was completed separately, focused specifically on the environmental consequences of climate change impacts. The results of this analysis are shown in Table R-7 below.

**Table R-7: Environmental Resource-focused Climate Impact Risk Analysis**

| | Low Likelihood (<3.5) | Medium Likelihood (3.5-4.5) | High Likelihood (4.5-5) |
|---|---|---|---|
| **Low Consequence (<3)** | State recommendations suggest no new critical facilities be built within the 200-year floodplain (DWR 2008, DWR 2009b, CNRA 2009)<br>Higher rainfall and increased risk of fires in watershed lands can lead to increased sediment loading to reservoirs | Changes in rainfall patterns may be problematic for timing of releases from reservoirs<br>Rangelands are expected to be drier | Domestic landscaping water needs will be higher<br>Coastal levees and control structures will be undersized to manage the combined influences of higher flow events and sea level rise |
| **Medium Consequence (<4)** | Lower seasonal surface flows can lead to higher pollutant concentrations<br>Migration patterns and species distribution will change<br>Invasive species populations will expand | Changes in storm intensity will increase sediment loading in many systems<br>Channel stability will be impacted from higher storm flows causing additional turbidity<br>Regional levees will provide less protection during higher storm flow events<br>Natural creeks throughout the region and managed conveyance within the Salinas Valley will see higher flow rates leading to increased erosion and flooding | |
| **High Consequence (<5)** | Some locally unique species such as coastal redwoods and giant kelp are susceptible to changes in certain locally favorable climate variables (fog duration, coastal upwelling) | Local rainfall is estimated to be reduced by 3-10 inches<br>Droughts will be more frequent and severe<br>Sea level rise will impact current estuary brackish water interface towards more marine systems<br>Coastal wetland systems are especially vulnerable to the combined influences of climate change | Agricultural water use is expected to increase to offset higher temperatures and evapotranspiration<br>Sea level rise and higher groundwater extraction will lead to increased rates of saltwater intrusion |

### R.4.2.e Prioritization of Impacts from Changes in Climate Variables

Table R-8 below outlines "priority impacts" for the Greater Monterey County Region. Priority impacts are defined as those that are more likely to occur and that will lead to significant impacts if they do occur. Priority impacts for the Greater Monterey County region were determined according to methods described by ICLEI and utilized by the City of Santa Cruz. Table R-8 depicts the relative risk of each climate change impact scenario, along with a relative level of urgency to act (priority level). The table illustrates results separately for all five socio-economic and environmental consequences (i.e., public safety, local economy and growth, community and lifestyle, environment and sustainability, and public administration) and for the environmental consequence only. This initial "priority impact" assessment was used by the Climate Task Force to prioritize implementation actions and future studies.

**Table R-8: Determining Priority Impacts: Prioritized Impacts Based on the Combined Consequences of All Five Social-economic Factors and for Environmental Consequence Alone**

| Potential Climate Change Impact | Risk Score (c x I) | Priority Level | Risk Score (c x I) | Priority Level |
|---|---|---|---|---|
| **Water Supply** | **Based on All Five Consequences** | | **Environmental Consequence Only** | |
| Agricultural water use is expected to increase to offset higher temperatures and evapotranspiration | 62 | High | 19 | Extreme |
| Rangelands are expected to be drier | 49 | Medium | 15 | High |
| Domestic landscaping water needs will be higher | 51 | Medium | 15 | High |
| Local rainfall changes are estimated to be reduced by 3-10 inches | 61 | High | 17 | Extreme |
| Sea level rise and higher groundwater extraction will lead to increased rates of saltwater intrusion | 66 | High | 17 | Extreme |
| Droughts will be more frequent and severe | 59 | High | 16 | Extreme |
| **Water Quality** | **Based on All Five Consequences** | | **Environmental Consequence Only** | |
| Lower seasonal surface flows can lead to higher pollutant concentrations | 39 | Low | 12 | High |
| Changes in storm intensity will increase sediment loading in many systems | 48 | Medium | 13 | High |
| Channel stability will be impacted from higher storm flows causing additional turbidity | 39 | Low | 11 | Medium |
| **Flooding** | **Based on All Five Consequences** | | **Environmental Consequence Only** | |
| Regional levees will provide less protection during higher storm flow events | 69 | High | 13 | High |
| Natural creeks throughout the region and managed conveyance within the Salinas Valley will see higher flow rates leading to increased erosion and flooding | 54 | Medium | 12 | High |
| Coastal levees and control structures will be undersized to manage the combined influences of higher flow events and sea level rise | 89 | Extreme | 17 | Extreme |
| State recommendations suggest no new critical facilities be built within the 200-year floodplain (DWR 2008, DWR 2009b, CNRA 2009) | 23 | Low | 3 | Low |
| **Ecosystem Vulnerabilities** | **Based on All Five Consequences** | | **Environmental Consequence Only** | |
| Sea level rise will impact current estuary brackish water interface towards more marine systems | 50 | Medium | 16 | Extreme |

| | | | | |
|---|---|---|---|---|
| Migration patterns and species distribution will change | 37 | Low | 13 | High |
| Invasive species populations will expand | 38 | Low | 10 | Medium |
| Coastal wetland systems are especially vulnerable to the combined influences of climate change | 45 | Medium | 16 | Extreme |
| Some locally unique species such as coastal redwoods and giant kelp are susceptible to changes in certain locally favorable climate variables (fog duration, coastal upwelling) | 37 | Low | 13 | High |
| **Hydropower and Reservoir Storage** | **Based on All Five Consequences** | | **Environmental Consequence Only** | |
| Changes in rainfall patterns may be problematic for timing of releases from reservoirs | 47 | Medium | 10 | Low |
| Higher rainfall and increased risk of fires in watershed lands can lead to increased sediment loading to reservoirs | 37 | Low | 9 | Medium |

### R.4.2.f Top Priority Climate Risks for the Greater Monterey IRWM Region

The climate risk analyses and priority impact assessment indicate the following climate risks to be top priority for the RWMG and other water managers in the Greater Monterey County IRWM region for considering how to adapt the region's water management systems for climate change impacts:

- ***Decreased water supply*** due to changes in precipitation, more frequent and severe droughts, increased surface and groundwater consumption, and increased seawater intrusion (due to sea level rise affecting coastal aquifers).
- ***Increased flooding and erosion of creeks and rivers*** due to more intense storm events (higher river flow rates), and overburdening of conveyance systems, levees, and culverts.
- ***Coastal inundation of urban development and other land uses, and impacts to river and wetland ecosystems*** due to changes in rainfall patterns, storm intensity, storm surges (due to increased storm intensity) and sea level rise.

### R.4.2.g Adaptive Capacity

The Greater Monterey County region's ability to respond to a given climatic impact enables us to reduce either the likelihood or consequence of an event. The ability to adapt to sea level rise, for example, can occur in many forms, including coastal armoring and protection, the raising of infrastructure, and inland retreat. Mathematically, this adaptive capacity is quantified as a number from 0 to 1, with a value of 0 indicating that adaptation is free and instantaneous and a value of 1 indicating that adaptation is impossible. Each adaptive measure provides a certain level of additional protection for a certain period of time for a certain cost. Significant resources are required to fully evaluate the adaptive capacity of any social-economic factor to a given climatic variable. Numerous engineering (hard) and adaptive planning (soft) measures need to be evaluated and cost benefit analyses must be completed. The Climate Task Force emphasized the additional need to evaluate and quantify secondary unintended consequences of any adaptive measure to all of the social-economic factors defined within this chapter. Because of the complexity of this process, adaptive capacity was not systematically evaluated by the RWMG. Given adequate funding, the RWMG hopes to conduct such an analysis in the future. An example of an Adaptive Capacity Analysis is provided in Table R-9 below.

**Table R-9: Example of an Adaptive Capacity Analysis**

| Impact | Strategy | Feasibility | Estimated Cost | Key Partners |
|---|---|---|---|---|
| Coastal levees and control structures will be undersized to manage the combined influences of higher flow events and sea level rise | Raise levees, replace tide gates, and expand pumping infrastructure. | Very feasible. Pumping requirements dependent on watershed flows and sea level. Seawater intrusion of shallow groundwater a key management concern. | Extremely high – Pump requirements for watershed are significant. | Monterey County Water Resources Agency |
| | Easements for retired low-lying areas most vulnerable to coastal inundation. Protection of critical infrastructure. | Feasible – privately held rolling easements have occurred elsewhere. Dependent on policy decisions regarding cost allocation for other options. | High – dependent on acreage. | Monterey County Planning, FEMA |

### R.4.2.h Vulnerability

Where *Risk* = *Likelihood* x *Consequence*, *Vulnerability = Likelihood x Consequence x Adaptive Capacity*. Vulnerability is the interpretation of the above variables leading to the conclusion: how likely is it that an event will occur, how bad will the impact be, and can we do anything about it? An analysis of the cost and effectiveness of the various adaptive measures must be completed prior to understanding the region's vulnerability to various environmental impacts. An interim step towards completion of an evaluation of the region's vulnerability to future coastal inundation is to consider the 1995 and 1998 el Niño floods, evaluate the likelihood that such events will occur again, and infer the region's adaptive capacity currently (in 2012).

## R.5 INITIAL ADAPTATION STRATEGY

The following section describes the RWMG's initial adaptation strategy for addressing impacts to water resources in the Greater Monterey County IRWM planning area, based on the results of the initial risk assessment described above. This initial adaptation strategy will become more developed over time by the RWMG and Climate Task Force as more climate change data and analytical tools are generated.

### R.5.1 No Action Response

The Proposition 84/1E Guidelines state that decisions about adapting water management systems, as well as mitigating climate change through reductions in GHG emissions, should take into account the risks to the region of no action. The results of a "no action" response have essentially been described by the various climate change scenarios outlined in the sections above. The RWMG considers the "no action" response to be an irresponsible and reckless response, given the predicted consequences of climate change for human life, the local economy, and natural resources in the region. The RWMG is actively pursuing climate change adaptation and mitigation strategies, as described below.

### R.5.2 Adaptation Goals and Objectives

The Greater Monterey County IRWM region's initial adaptation goals and objectives, listed below, have been selected from a comprehensive list of potential actions within the DWR guidance document. The goals are intended to direct focus towards the three priority Climate Risks identified above as well as the water resource goals and objectives defined within the Greater Monterey County IRWM Plan (see Section D, Objectives). The adaptation goals and objectives form the foundation for the RWMG's initial adaptation strategy for the Greater Monterey County region. The goals document specific responses to the priority Climate Risks that can be accomplished by the various IRWM partner agencies and stakeholders and do not need to be managed or actively coordinated by the RWMG. Rather, the Greater Monterey County IRWM planning effort can serve as a forum to hear ideas and results of projects aimed to address these goals by numerous entities.

**Adaptation Goals**

The Greater Monterey County IRWM Plan recognizes the importance of becoming a climate resilient region. Adaptation goals that support that intention include:

- Encourage adaptation activities that increase the resiliency of local communities, businesses, and institutions to changes in the climate.
- Minimize the potential for injury of citizens and damage to public and private property from climate change related impacts.
- Increase the resilience of municipal departments to adapt and respond to climate related emergencies.
- Protect natural lands, agricultural areas, and coastal resources from the future threats of climate change to increase the resilience of communities.
- Do not permit the construction of new critical facilities within the 200-year flood plain (per State recommendations).
- Plan for effective adaptation and resiliency that supports proactive steps towards sustainability rather than response through unplanned emergency actions.

**Adaptation Objectives**

- Implement on-going climate change variable monitoring to inform adaptation and response efforts.
- Develop regional sea level rise resiliency strategies to prepare for impacts to water resource infrastructure and lands, that support the multiple benefits described in the IRWM Plan, and that consider short and long-term economic implications.
- Consider potential climate change impacts to water resources in future land use and regional resource planning of the county and other municipalities.
- Support regional collaborations and planning efforts, and provide information to the public regarding potential climate change impacts and status of response planning.
- Encourage the retrofit or relocation of water infrastructure that is vulnerable, and evaluate changes to water management strategies that are likely to be less effective due to climate change.
- Prioritize the protection of drinking water resources and sensitive water supplies and aquatic ecosystems that support a sustainable region.

### R.5.3 Adaptation Actions and Response

To develop an adaptation strategy for the Greater Monterey County IRWM region, adaptation actions and response scenarios from the California Natural Resources Agency's *2009 California Climate Adaptation Strategy* were selected as applicable to the Greater Monterey County region. High priority responses along with climate mitigation actions are listed in Table R-10, "Adaptation and Response Strategies Based on Risk Assessment," below. The "high priority responses" were prioritized by the Climate Task Force according to the risk assessment described above and in accordance with the objectives of the Greater Monterey County IRWM Plan. Both the comprehensive risk assessment (i.e., that heavily favors human impacts as priorities) and the environmental risk assessment are presented together in Table R-10. We anticipate that these distinctions in prioritization will better enable IRWM Plan participants to respond to funding opportunities that focus specifically on water infrastructure projects or environmental resource protection.

This prioritized list of adaptation actions is considered a first step toward developing a comprehensive adaptation strategy for the Greater Monterey County IRWM planning region to address the impacts of climate change. These adaptation and climate mitigation actions will be further evaluated by the RWMG in collaboration with the Climate Task Force to define next steps, responsible entities, and funding resources to complete adaptation actions. As more tools become available, the RWMG will be able to consider more specific risks to the region due to climate change, better understand the tradeoffs and benefits of different adaptations, and will be able to identify additional adaptations relevant to the region. The adaptation strategy will consider the extent to which existing water management systems in the region—including man-made and natural water systems—are adaptable to climate change impacts and the steps that would need to be taken, along with associated costs, to make those systems more robust. The process will include a cost-effectiveness analysis and a final prioritization of adaptation actions, focusing on specific water management systems throughout the region. In addition, specific consideration will be afforded to strategies that offer multiple benefits through use of natural services.

**Table R-10: Adaptation and Response Strategies Based on Risk Assessment**

| Climate Change Consequences | Including All Consequences | | Environment and Sustainability Consequence Only | | Adaptation and Response Strategies | Initial Actions |
|---|---|---|---|---|---|---|
| | Risk Score (c x l) | Priority Level | Risk Score (c x l) | Priority Level | | |
| **Water Demand** | | | | | | |
| Agricultural water use is expected to increase to offset higher temperatures and evapotranspiration | 62 | High | 19 | Extreme | • Promote community resilience to reduce vulnerabilities: food sustainability | • Expand water supplies (purple pipe) and storage<br>• Aquifer management<br>• Expand agriculture water conservation programs |
| Rangelands are expected to be drier | 49 | Medium | 15 | High | • Prepare fire reduction strategies to protect watershed lands using ecologically sustainable strategies.<br>• Implement adaptation strategies to conserve California's biodiversity. | N/A |
| Domestic landscaping water needs will be higher | 51 | Medium | 15 | High | • Integrate land use and climate adaptation planning | • Education<br>• Incentive programs<br>• Demonstration programs<br>• Grey water<br>• Xeriscaping<br>• Expand water supplies (purple pipe) and storage<br>• Aquifer management<br>• Expand domestic conservation programs |
| Local rainfall is estimated to be reduced by 3-10 inches | 61 | High | 17 | Extreme | • Promote community resilience to reduce vulnerabilities: Food sustainability<br>• Implement water conservation and supply management efforts<br>• Manage watersheds, habitat, and vulnerable species | • Education<br>• Incentive programs<br>• Demonstration programs<br>• Grey water<br>• Xeriscaping<br>• Aquifer management<br>• Expand agriculture water conservation programs |
| Sea level rise and higher groundwater extraction will lead to increased rates of saltwater intrusion | 66 | High | 17 | Extreme | • Prepare a regional sea level rise adaptation strategy<br>• Promote working landscapes with ecosystem services<br>• Integrate land use and climate adaptation planning | • Education<br>• Incentive programs<br>• Demonstration programs<br>• Grey water<br>• Xeriscaping<br>• Expand water supplies (purple pipe) and storage<br>• Aquifer management<br>• Expand agriculture water conservation programs<br>• Groundwater barriers<br>• More robust monitoring and testing |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | • Easements for retired farmland |
| Droughts will be more frequent and severe | 59 | High | 16 | Extreme | • Implement adaptation strategies to conserve California's biodiversity<br>• Educate, empower, and engage citizens regarding risks and adaptation<br>• Integrate land use and climate adaptation planning<br>• Promote community resilience to reduce vulnerabilities | • Human safety response<br>• Education<br>• Incentive programs<br>• Demonstration programs<br>• Grey water<br>• Xeriscaping<br>• Expand water supplies (purple pipe) and storage<br>• Aquifer management<br>• Expand agriculture and urban water conservation programs<br>• Groundwater barriers<br>• More robust monitoring and testing<br>• Easements for retired farmland |
| **Water Quality** | | | | | | |
| Lower seasonal surface flows can lead to higher pollutant concentrations | 39 | Low | 12 | High | • Manage watersheds, habitat, and vulnerable species | • Minimize non-point source pollution<br>• Buffers |
| Changes in storm intensity will increase sediment loading in many systems | 48 | Medium | 13 | High | • Prepare fire reduction strategies to protect watershed lands using ecologically sustainable strategies | • Erosion control on farms and creeks<br>• Buffers |
| Channel stability will be impacted from higher storm flows causing additional turbidity | 39 | Low | 11 | Medium | • Provide guidance on protecting critical coastal ecosystems and development | • Erosion control on creeks<br>• Wastewater and stormwater infrastructure vulnerability analysis |
| Sea level rise will impact current estuary brackish water interface towards more marine systems | 50 | Medium | 16 | Extreme | • Implement adaptation strategies to conserve California's biodiversity | • Retain freshwater in watershed<br>• Habitat migration<br>• Buffers<br>• Erosion control<br>• Conservation easements<br>• Xeriscaping |
| **Flooding** | | | | | | |
| Regional levees will provide less protection during higher storm flow events | 69 | High | 13 | High | • Support essential data collection and information sharing<br>• Manage watersheds, habitat, and vulnerable species<br>• Prepare a regional sea level rise adaptation strategy | • Refurbish or expand levees or tide gates (upgrade priority infrastructure)<br>• Map/inventory infrastructure |

| | | | | | | |
|---|---|---|---|---|---|---|
| Natural creeks throughout the region and managed conveyance within the Salinas Valley will see higher flow rates leading to increased erosion and flooding | 54 | Medium | 12 | High | • Manage watersheds, habitat, and vulnerable species | • Refurbish or expand levees or tide gates (upgrade priority infrastructure)<br>• Map/inventory infrastructure |
| Coastal levees and control structures will be undersized to manage the combined influences of higher flow events and sea level rise | 89 | Extreme | 17 | Extreme | • Support essential data collection and information sharing<br>• Prepare a regional sea level rise adaptation strategy | • Refurbish or expand levees or tide gates (upgrade priority infrastructure)<br>• Map/inventory infrastructure/levee locations and WCS, ownership<br>• Phase II task 5 activity 3 - ecosystem services - be aware of services available<br>• Elevations of levees and sea walls - maybe with PWA-management strategies<br>• USGS elevation data?<br>• Channel dredging<br>• Ecological restoration |
| State recommendations suggest no new critical facilities be built within the 200-year flood plain (DWR 2008, DWR 2009b, CNRA 2009) | 23 | Low | 3 | Low | • Integrate land use and climate adaptation planning | • Work with Monterey County and cities, Coastal Commission (local jurisdiction) |
| **Aquatic Ecosystem Vulnerabilities** | | | | | | |
| Migration patterns and species distribution will change | 37 | Low | 13 | High | • Establish a system of sustainable habitat reserves | • Reduce migration impediments (dams, etc.)<br>• Compile data on species distribution<br>• Primary focus species - amphibians, waterfowl, salmonids, redwoods, tide water gobies<br>• Maintain habitat corridors - contiguous areas<br>• Fish and Game - wildlife adaptation plan - vulnerability for key species for each region<br>• Remove barriers |
| Invasive species populations will expand | 38 | Low | 10 | Medium | • Habitat/ecosystem monitoring and adaptive management | • What are the invasive species and their ranges? Will they expand, be introduced? How are the habitats shifting (awareness)?<br>• Ecological adaptation investigation and strategy<br>• Model range shifts with climate change |

| | | | | | | |
|---|---|---|---|---|---|---|
| Coastal wetland systems are especially vulnerable to the combined influences of climate change | 45 | Medium | 16 | Extreme | • Establish regional policies to protect critical habitats<br>• Provide guidance on protecting critical coastal ecosystems and development | • Identify critical habitats and ecosystems<br>• Integrate ecosystem management<br>• Regulatory mechanisms dedicated to protecting future locations of these areas<br>• Inventory of wetlands currently<br>• What lands are adjacent?<br>• Rolling easement for ag - retired ag lands<br>• Hazard mitigation |
| Some locally unique species such as coastal redwoods and giant kelp are susceptible to changes in certain locally favorable climate variables (fog duration, coastal upwelling) | 37 | Low | 13 | High | • Manage watersheds, habitat, and vulnerable species | • Identify how they will be impacted - What are the changes?<br>• USGS study outcome - get a better handle on modeling fog changes in climate change |
| **Hydropower and Reservoir Storage** | | | | | | |
| Changes in rainfall patterns may be problematic for timing of releases from reservoirs | 47 | Medium | 10 | Low | • Implement water conservation and supply management efforts | • Modified flood control operations<br>• Opportunities for more water storage<br>• Maintain optimum flow capacity in channels<br>• San Antonio and Nacimiento Reservoirs and rainfall – potential for interlake tunnel |
| Higher rainfall and increased risk of fires in watershed lands can lead to increased sediment loading to reservoirs | 37 | Low | 9 | Medium | • Prepare fire reduction strategies to protect watershed lands using ecologically sustainable strategies | • Fire prevention<br>• Forest management - FireScape Monterey<br>• Rangeland management (much of the area around the reservoirs is grassland)<br>• Erosion control for infrastructure surrounding reservoirs |

### R.5.4 No Regret Strategies

Since the tools to properly assess the risk of any one effect of climate change in the region are currently not well developed, the RWMG encourages the implementation of so-called "no regret" adaptations to general effects of climate change. Such adaptations are those that make sense in light of the current water management context for the region and also help in terms of effects of climate change. Examples of "no regret" strategies include increasing water use efficiency, practicing integrated flood management, and enhancing ecosystems and their ability to provide multiple benefits to the region. The RWMG generally encourages the implementation of "no regret" strategies through the IRWM Plan and gives higher priority to these strategies in the project ranking process by providing additional points under the "Climate Change" categories.

### R.5.5 Next Steps towards Climate Preparedness

***Preparing for the Future: Climate Change and the Monterey Bay Shoreline***

As noted previously, on December 6, 2011, the MBNMS and Center for Ocean Solutions convened regional decision makers at a one-day workshop titled "Preparing for the Future: Climate Change and the Monterey Bay Shoreline."[10] The event was the first Monterey Bay region-wide gathering on climate change adaptation, intended to facilitate a discussion on how to best prepare coastal communities in the Monterey Bay region to adapt to the impacts of climate change. More than 90 people attended from cities and municipalities in Santa Cruz and Monterey Counties, representing city and county staff, state and federal governments, research institutions and nonprofit organizations. They heard from featured experts and participated in breakout group sessions. Examples of climate change adaptation plans from government jurisdictions around the country were also shared at the workshop. The workshop demonstrated to participants that past experience with storms and strong El Niño conditions provide the Monterey Bay region with concrete examples of what increased sea level and storm intensity may mean for the area's future.

*Workshop goals for participants were to:*

- Begin Monterey Bay region-wide discussion and collaboration on climate change adaptation
- Understand the latest research on climate change impacts to the Monterey Bay coastline
- Gain a basic understanding of the typical climate change adaptation planning process
- Witness how communities in the Monterey Bay area are already planning for climate change
- Learn about grant opportunities and other resources (tools, assistance) available to support climate change adaptation planning
- Have the opportunity to develop new collaborations and partnerships in climate change adaptation planning

*During the workshop, the following themes emerged:*

- If Monterey Bay communities start now, they will have time to prepare for the impacts of climate change on their coast. Past storms provide examples of the range of impacts to expect from changes in sea level and storminess as a result of climate change
- A range of tools and resources currently exists for climate change adaptation planning
- Uncertainty in local projections is unavoidable so communities should not wait for perfect information to begin adaptation planning
- There are very real and difficult barriers to making progress in climate change adaptation, including lack of resources, unprecedented regulatory challenges, low perceived public support, and limited local data; yet by working collaboratively it is possible to overcome these challenges

[10] The information in this section has been excerpted from the workshop Summary Report (Abeles et al. 2012).

*Participants recommended the following next steps for the region:*

- Improve understanding of local impacts of climate change and develop actionable recommendations for moving forward
- Design and implement a governance structure for the Monterey Bay region that could aid and coordinate climate change adaptation and related activities
- Continue the discussion initiated at the workshop by building a regional network of people interested in or working on climate change adaptation
- Expand the scope of stakeholder involvement to include in-person discussions and engage coastal business owners, landowners and the general public
- Create a technical advisory group on climate change adaptation for the region
- Actively use the Internet as a way to connect and educate the regional community
- Jointly apply for funding to support coastal climate change adaptation work in the region
- Develop climate change projection data at a scale fine enough to use for local planning
- Consider a public engagement campaign to help increase awareness about the need for climate

Several members of the Greater Monterey County RWMG (in particular MBNMS, the Central Coast Wetlands Group, Elkhorn Slough National Estuarine Research Reserve, California Coastal Commission, and the Monterey Regional Water Pollution Control Agency) participated in the "Preparing for the Future" workshop, and the MBNMS and Central Coast Wetlands Group were instrumental in organizing the event. RWMG members will continue to stay involved in any "next steps" that result from the "Preparing for the Future" workshop, and will work to coordinate the IRWM planning efforts regarding climate change with this promising Monterey Bay regional effort. The Summary Report for the workshop, along with all workshop presentations, can be downloaded at: http://centerforoceansolutions.com/preparingforthefuture.

**R.5.6 Pilot Coastal Vulnerability Evaluation**

The Natural Capital Project and the Center for Ocean Solutions have worked with the Greater Monterey County RWMG and Climate Task Force to assess the effects of coastal adaptation strategies and climate scenarios on the ecosystem services provided by coastal and near shore environments. Phase I of this project 1) assessed the physical vulnerability of the coast to hazards such as erosion and inundation, and 2) assessed the vulnerability of relevant infrastructure, land use types, and coastal communities. This assessment can be used to identify areas for future analysis and inform project prioritization and funding. Analysis of these vulnerabilities were developed through the use of the Integrated Valuation of Environmental Services and Tradeoffs (InVEST) decision support tool—a family of tools to map and value the goods and services provided by nature. The Coastal Vulnerability11 model was utilized for Phase I of this project. Appendix K, "The Role of Natural Habitat in Coastal Vulnerability and Adaptation Planning," provides a full description of the assessment in the Greater Monterey County Planning region.

**R.5.7 Future Studies and Regional Data Needs**

As recognized in the climate risk assessment, priority actions to address local climate change impacts should focus on the three priority climate risks:

- *Decreased water supply*
- *Increased flooding and erosion of creeks and rivers*
- *Coastal inundation of urban development, other land uses, and impacts to coastal river and wetland ecosystems*

[11] http://ncp-dev.stanford.edu/~dataportal/invest-releases/documentation/current_release/#marine-models

The risk assessment process identified many data needs and research studies. The process also identified that the above risks pose specific hardships and challenges to each of the five different social, economic, and environmental factors described previously. The Climate Task Force developed an initial list of response strategies, initial actions, and data needs in response to the risk assessment. These strategies are based on the adaptation actions and response scenarios listed in the California Natural Resources Agency's *2009 California Climate Adaptation Strategy*, and prioritized as described in Section R.5.3 above. The Climate Task Force has agreed that future research and program funds should be directed towards the three priority climate risk areas above. In addition, future IRWM Plan projects should strive to help fill data gaps and promote the priority response strategies and initial actions. Specifically, the areas listed below should be integrated into future implementation projects.

**Land Use**

- Integrate land use and climate adaptation planning
- Promote community resilience to reduce vulnerabilities for food sustainability and DACs
- Educate, empower, and engage citizens regarding climate risks and adaptation
- Provide guidance on protecting critical coastal development

**Ecosystems**

- Implement adaptation strategies to conserve California's biodiversity
  - Support habitat/ecosystem monitoring and adaptive management
- Manage watersheds, habitat, and vulnerable species
- Provide guidance on protecting critical coastal ecosystems

**Water Conservation**

- Implement water conservation and supply management efforts
  - Support adaptive agricultural protection policies
  - Promote working landscapes with ecosystem services

**Coast and Ocean**

- Manage watersheds, habitats, and vulnerable species
  - Establish regional policies to protect critical habitats
  - Provide guidance on protecting critical coastal ecosystems and development
  - Promote working landscapes and ecosystem services
- Prepare a regional sea level rise adaptation strategy
  - Complete a regional sea level rise risk assessment periodically
- Support essential data collection and information sharing

**Carbon Mitigation**

- Expand renewable energy infrastructure that supports water management efforts

The Greater Monterey County RWMG met with the Climate Task Force and discussed each of these adaptation categories. The Climate Task Force supported the selection of these next steps, and has recommended that these ideas be integrated into project submittals for the following rounds of concept and implementation project proposals for the Greater Monterey County IRWM Plan.

### R.5.8 Initial Climate Adaptation Project

To ensure that the momentum developed by the Climate Task Force towards climate resilience planning was not lost, the Central Coast Wetlands Group at Moss Landing Marine Laboratories, a RWMG member, has submitted an implementation project proposal for inclusion in the Greater Monterey County IRWM Plan. The project is intended to provide resources to regional partners to compile the necessary information needed to understand the region's adaptive capacity to mitigate impacts associated with the priority climate risk factor, *Coastal inundation of urban development, other land uses, and impacts to river and wetland ecosystems*.

**Project Summary:**
The proposed project implements key steps in climate change planning outlined by the DWR 2011 *Climate Change Handbook for Regional Water Planning*. Phase I and Phase II of this project are based on the guidance provided within Sections 5 and 6 of the handbook.

During the review of this Climate Change chapter for the IRWM Plan, the Climate Task Force identified critical data gaps important to climate change planning, developed a methodology for running a vulnerability and risk assessment, and discussed next steps for climate change planning in the Greater Monterey County IRWM region. This project follows up on these topics, further and more accurately investigates regional climate change impacts, and seeks to recommend adaptation response strategies to address the impacts of sea level rise, storm surge, coastal inundation and coastal erosion.

The first phase of the project focuses on collecting and compiling data for the Elkhorn Slough, Gabilan, and Salinas River watersheds to further evaluate coastal inundation threats and responses in these watersheds. This data includes an inventory of water control structures (levees, culverts, tide gates, etc.) that manage current flood conveyance and topographic data using Light Detection and Ranging technology (LiDAR). These data will then be used to support an in-depth regional vulnerability analysis and risk assessment for coastal water control structures, communities, and ecosystems (defined as priority issues within the IRWM Plan vulnerability evaluation). The second phase of this project focuses on creating a climate change adaptation and response strategy plan followed by an economic evaluation of these different strategies. Response strategies will include nature-based responses and the economic and ecosystem effects of those responses. These tasks will enable resource managers and planners to better define alternative response strategies for each climatic risk and evaluate the feasibility, cost and longevity of each strategy. Resource managers can then correlate this information with land use and environmental valuation to prioritize responses. The outcome of this project will be a comprehensive report recommending feasible and long-term adaptation and response strategies to climate change impacts for the region. This project will help support the climate change planning efforts of multiple partners and stakeholders in the Greater Monterey County IRWM planning region.

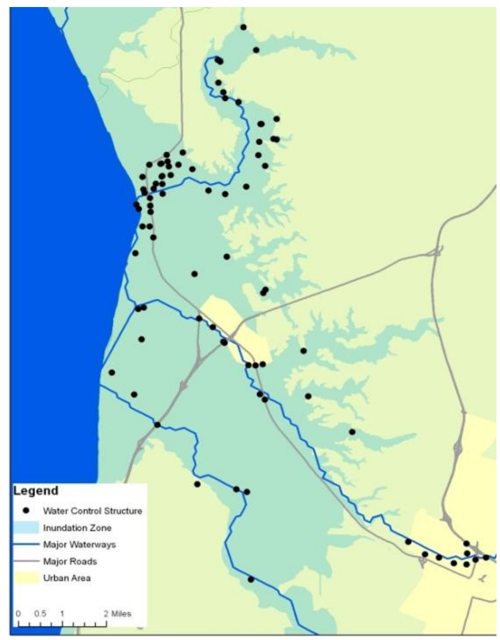



Figure 1. Preliminary inventory of water control structure locations overlaid with the Coastal Commission's priority SLR planning area.

The Climate Task Force will also work with DWR and the US Environmental Protection Agency to coordinate research opportunities and adaptation strategy development. One key action will be to conduct a regional adaptation study that integrates additional data collection with IRWM planning for the four IRWM Plans within the greater Monterey Bay region (i.e., the Greater Monterey County, Northern Santa Cruz County, Pajaro River Watershed, and the Monterey Peninsula, Carmel Bay, and South Monterey Bay regions).

## R.6 CLIMATE CHANGE MITIGATION AND GHG EMISSIONS REDUCTION STRATEGY

The development of a GHG emissions reduction strategy is a required component of an IRWM Plan. All aspects of water resources management have an impact on GHG emissions, including the development and use of water for habitat management and recreation; domestic, municipal, industrial, and agricultural supply; hydroelectric power production; and flood control. Water management results in the consumption of significant amounts of energy in California and the accompanying production of GHG emissions, especially where water must be pumped from long distances, from the ground, or over significant elevations. According to California Energy Commission November, *2005 CEC-700-2005-011 California's Water – Energy Relationship Final Staff Report*, 19 percent of the electricity and 30 percent of the non-power plant natural gas of the State's energy consumption are spent on water-related activities, primarily related to end-uses of water (i.e., what the customer does with the water). The close connection between water resource management and energy is an important consideration for helping the State meet its GHG emission reduction goals. IRWM Plans can help mitigate climate change by reducing energy consumption, especially the energy embedded in water use, and ultimately reducing GHG emissions.[12]

This IRWM Plan focuses on several sectors of emissions that are most directly linked to water management and that are most likely to not be addressed within other climate/GHG reduction strategies. Emissions sources to be addressed include:

- Emissions included in the County for the production and distribution of water
- Emissions from privately owned pumps
- Emissions from county staff fleet and private vehicle emission associated with water project construction and maintenance
- Emissions from energy generation that could be mitigated through renewable energy sources

### R.6.1 GHG Reduction Strategies

A full GHG emissions reduction strategy for the region will be created by Monterey County in the near future to meet State mandates (AB 32, CEQA). In the meantime, several effective GHG reduction strategies can be addressed by the IRWM Plan and the projects funded and managed by this working partnership. To address the emissions categories identified above, several key strategies and actions described in the *Climate Change Handbook for Regional Water Planning* can be encouraged by the RWMG through the IRWM planning process, including the following (US EPA Region 9 and DWR 2011):

**Emissions from water supply and delivery**

- Select energy sources with low carbon content (green electricity purchases)
- Prioritize pump and infrastructure upgrades based on energy efficiency
- Reduce water use by all sectors of the community through conservation and water efficient irrigation
- Install solar PV at remote pump and infrastructure sites and provide incentives for private investment in solar for similar infrastructure
- Schedule pumping to reduce peak hour (12:00-5:00pm) energy use that has the highest carbon content

**Staff fleet and commute**

- Encourage carpooling
- Invest in energy efficient/low carbon fleet vehicles
- Encourage efficient driving practices

[12] This introductory paragraph has been excerpted from the Proposition 84/1E Program Guidelines, pp. 71-72.

**Emissions from IRWM Plan project construction**

- Encourage carpooling within construction contracts
- Encourage use of B20 fuels in construction equipment and other diesel machinery
- Invest in high efficiency pumps and control equipment
- Integrate solar generation in appropriate projects

**Renewable energy generation**

- Encourage investment in solar and other renewable energy generation options in Greater Monterey County IRWM region facilities
- Work with regional waste district to increase electricity generation from farm-generated food and animal bio-waste
- Increase hydro-electric generation within current water infrastructure

The RWMG can encourage the reduction of GHG emissions for IRWM Plan implementation projects through the project review and ranking process. The RWMG can also use the IRWM planning process to coordinate with water managers and land use planners throughout the Greater Monterey County region in order to encourage broader implementation of these and other GHG reduction and climate mitigation actions. The recommended GHG reduction and climate mitigation actions will be further evaluated by the RWMG, with substantial input from a Climate Task Force, to define possible next steps, responsible entities, and funding resources.

### R.6.2 Other Climate Change Mitigation/GHG Reduction Activities in the Central Coast Region

The RWMG has been communicating with water managers and land use managers in the broader Central Coast region regarding other climate change mitigation/GHG reduction efforts along the Central Coast. The RWMG will seek to partner in these and similar efforts as opportunities arise. Regional climate change mitigation/GHG reduction programs include the following.

***Climate Action Compact***

In October 2007, the County of Santa Cruz, the City of Santa Cruz, and the University of California Santa Cruz partnered to create a Climate Action Compact (CAC). The goal of the CAC is to achieve meaningful and measurable progress towards lowering local GHG emissions through the implementation of cooperative programs. To that end, the CAC partners initiated a process to develop actions necessary to accomplish the goals outlined in the compact. In 2011 CAC members reached out to all municipalities within the Monterey Bay region, including the area covered by the Greater Monterey County IRWM Plan, to join and participate in collaborative GHG reduction efforts. The members pledged to support public, private, and nonprofit partnerships and investments to reach quantifiable reductions in their institutions' GHG emissions (Clark 2011). In taking this leadership role, the CAC partners pledged themselves to the following:[13]

- Set and present a GHG reduction goal for their respective organizations;
- Identify specific inter-institutional cooperative projects that reduce GHG emissions, stimulate investment in the community, and foster economic development;
- Present a comprehensive GHG reduction action plan for their respective organizations; and
- Immediately invite others from the public, private, and non-profit sectors in the region to join in the effort.

[13] Source: City of Santa Cruz CAC website: http://www.cityofsantacruz.com/index.aspx?page=1231 (March 2012).

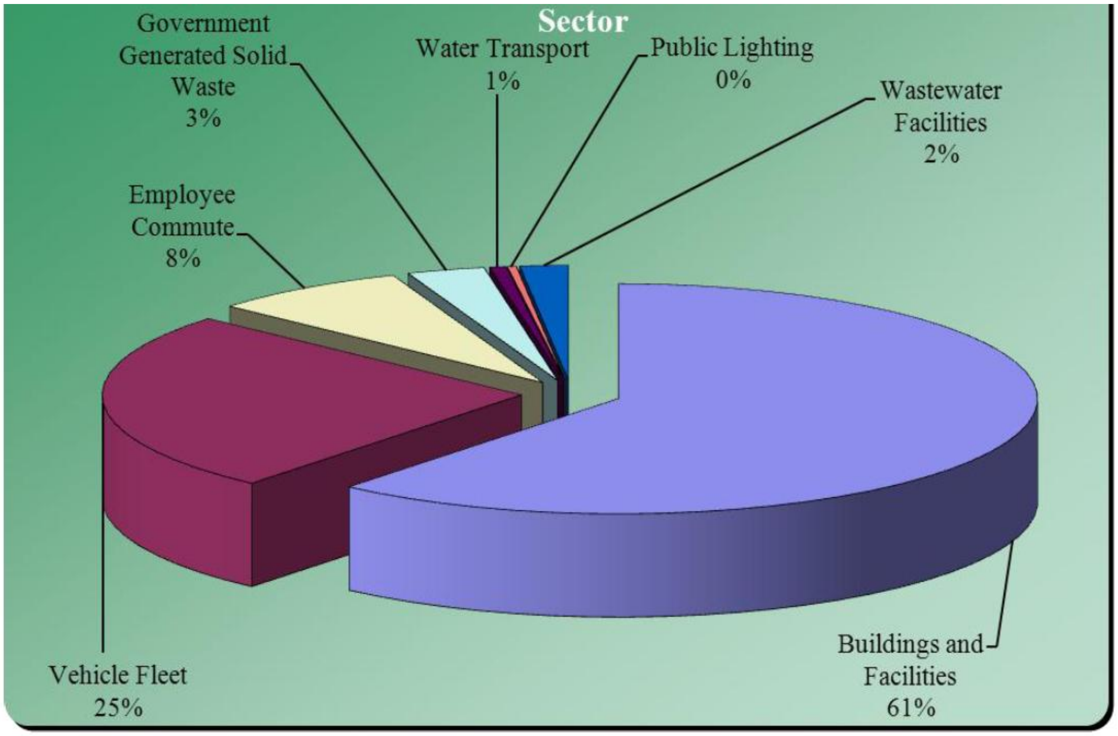
***Association of Monterey Bay Area Governments Programs***

AMBAG has developed regional emission targets in accordance with requirements of SB 375. AMBAG has also initiated a program in collaboration with the Pacific Gas and Electric Company (PG&E) called "Energy Watch." The Energy Watch Program helps local governments in Monterey, San Benito, and Santa Cruz counties to promote energy efficiency and climate action planning. This collaboration has included preparation of GHG emissions inventories.

In early 2011, the AMBAG Energy Watch Program completed a GHG emissions inventory for Monterey County for the year 2005. The inventory for Monterey County was developed using the "Clean Air and Climate Protection" software developed by ICLEI. The inventory examines emissions by community sector and includes direct and indirect emissions. The study also predicts that under a "business-as-usual" scenario, Monterey County GHG emissions are estimated to grow by approximately 9 percent by the year 2020, which represents an average annual rate of increase of about 0.6 percent per year with the total increase between 2005 and 2020.

In 2010, AMBAG completed a set of GHG inventories for all of its 21 municipal members. The cumulative emissions from the unincorporated areas of Monterey County were quantified for various sectors including municipal (county government) residential and commercial/industrial. For 2005, countywide emissions were calculated to be 1,648,410 metric tons. Of that total, municipal emissions comprised 1.3 percent (21,641 tons); and of the municipal emissions total, emissions from municipal supply and distribution of water resources were 0.6 percent (133 tons). Figure R-8 below illustrates emissions from local government operations for Monterey County, by sector. Additional emissions attributable to water management in the Greater Monterey Region that are not included in this calculation include: emissions from small water purveyors, private well and flood management pump infrastructure, and the emissions associated with water agency fleet and staff vehicles used to manage the vast water resource infrastructure of the region.

**Figure R-8: 2005 GHG Emissions from Monterey County Government Operations**




**Source:** AMBAG 2011, Monterey County Greenhouse Gas Emissions Inventory. Used by permission.