# CALIFORNIA CLIMATE CHANGE
# ADAPTATION POLICY GUIDE

DRAFT

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CALIFORNIA EMERGENCY MANAGEMENT AGENCY

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# California Climate Change
# Draft Adaptation Policy Guide

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# ADAPTATION POLICY GUIDE
# PART 1: INTRODUCTION AND FRAMEWORK

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# Part 1- Introduction and Framework

**1.0 Introduction**
1.1 Adaptation Policy Guide – Purpose, Intent, and Organization
1.2 The Importance of Community Action
1.2.1 Community Engagement

Climate change is already affecting California and is projected to continue to do so well into the foreseeable future (CNRA, 2009; Moser et al., 2009). Current and projected climate changes include increased temperatures, sea level rise (SLR), a reduced winter snowpack, altered precipitation patterns, and more frequent storm events.

Over the long term, reducing greenhouse gases (GHG) can help make these changes less severe, but the changes cannot be avoided entirely. Unavoidable climate impacts can result in a variety of secondary consequences including detrimental impacts on human health and safety, economic continuity, ecosystem integrity, and provision of basic services (CNRA, 2009; CIG, 2007). These potential consequences can pose enough of a threat that they demand attention even if the outcomes are not certain.

California Department of Water Resources

***Climate Change Impacts of Concern to Communities (from the 2009 California Climate Adaptation Strategy)***

- Climate change is expected to lead to increases in the frequency, intensity, and duration of extreme heat events and heat waves in California, which is likely to increase the risk of mortality and morbidity due to heat-related illness and exacerbation of existing chronic health conditions. (p. 39)
- Higher temperatures will melt the Sierra snowpack earlier and drive the snowline higher, resulting in less snowpack to supply water to California users. (p. 84)
- Intense rainfall events, periodically ones with larger than historical runoff, will continue to affect California with more frequent and/or more extensive flooding. (p. 84)
- Droughts are likely to become more frequent and persistent in the 21st century. (p. 84)
- Storms and snowmelt may coincide and produce higher winter runoff from the landward side, while accelerating sea-level rise will produce higher storm surges during coastal storms. Together, they increase the probability of levee failures in the Sacramento-San Joaquin Delta. (p. 85)
- The most significant climate change risk facing California is associated with an increase in wildfire activity. Warmer weather, reduced snowpack and earlier snowmelt can be expected to increase fuel hazards and ignition risks. It can also increase plant moisture stress and insect populations, both of which impact forest health and reduce forest resilience to wildfires. An increase in wildfire will increase public safety risks, property damage, fire suppression and emergency response costs to government, watershed and water quality impacts, vegetation conversions and habitat fragmentation. (p. 112)
- Sea-level rise will increase erosion of beaches, cliffs, and bluffs, threatening public and private property and structures and causing social, economic, and resource losses to coastal recreation and tourism through reduction in or damage to beaches, access ways, parks, trails, and scenic vistas. (p. 71)
- The economic cost associated with the required alteration, fortification, or relocation of existing Infrastructure [due to sea-level rise] is likely to be in the tens of billions. (p. 129)

The California Climate Adaptation Policy Guide (APG) provides a method to aid local and regional entities in evaluating vulnerability and devising strategies to address these impacts. "Climate adaptation" refers to strategies (policies, programs, or other actions) that seek to bolster community resilience in the face of unavoidable climate impacts. Several state agencies have begun developing climate adaptation strategies and guidance (e.g., CEC, 2005; DPR, 2007; BCDC 2009; CEC, 2009; CNRA, 2009; DWR, 2011).

State actions will play an important role in strengthening California's resilience to projected climate impacts and associated secondary consequences. However, many of the development characteristics most important for reducing climate risks, such as land use, are locally controlled. Local and regional jurisdictions are critical collaborators in preparing for unavoidable climate impacts. The degree to which communities are at risk to secondary climate impacts is influenced by local conditions including culture and community values, economic base, ecological setting, and local resources. As a result, there is no single "right" adaptation strategy. The best strategies for adapting to climate change must vary with local needs and context.

## 1.1 Adaptation Policy Guide – Purpose, Intent, and Organization

To support the efforts of local and regional entities seeking to develop adaptation policies, the California Climate Adaptation Policy Guide (APG) provides a clear set of steps, along with links to available data and resources. The intended users of the guide are local and regional policy-makers. Use of the guide does not require technical expertise in climate science, but it does require users to gather information about their community. The APG seeks to provide context and a framework in which to use this information and apply climate adaptation guidance on a local level.
There are many guidance documents available, including those produced by California state agencies (e.g., CNRA, 2009; CEC, 2009; DPR, 2007; DWR, 2011; BCDC, 2009). The APG differs from these efforts by focusing specifically on adaptation at the local and regional scale. This focus influences in the included content. The climate impacts discussed and the adaptive measures included in the APG are those that are within the jurisdiction of local governments and regional organizations.

*California Climate Policy Summary*

**Executive Order S-03-05.** The initial push for greenhouse gas reduction was set in motion by Executive Order S-03-05 in 2005, which established climate change emission reduction targets for the state for the purpose of mitigating global warming.

**AB 32 – California Global Warming Solutions Act.** In 2006 the California legislature passed and the Governor signed Assembly Bill (AB) 32, known as the California Global Warming Solutions Act. The law established a comprehensive program to achieve quantifiable, cost-effective reductions of greenhouse gases on a scheduled basis. It required the California Air Resources Board (ARB) to develop regulations and market mechanisms that would ultimately reduce California's greenhouse gas emissions by 25 percent by 2020. It required the ARB to adopt a plan by January 1, 2009, indicating how emission reductions would be achieved from significant greenhouse gas sources, and to adopt regulations by January 1, 2011 to achieve maximum technologically feasible and cost-effective reductions in greenhouse gas. Mandatory caps would be set in 2012 for significant sources.

**SB 97 – CEQA Guidelines for Mitigating Greenhouse Gas Emissions.** Also in 2006 the legislature passed Senate Bill 97 which directed the Governor's Office of Planning and Research (OPR) to develop draft CEQA Guidelines "for mitigation of greenhouse gas emissions or the effects of greenhouse gas emissions" by July 1, 2009. The CEQA Guidelines Amendments, adopted by the California Natural Resources Agency on December 30, 2009, provide guidance to public agencies regarding analysis and mitigation of greenhouse gas emissions in draft CEQA documents.

**SB 375 – Sustainable Communities and Climate Protection Act.** In 2008 the legislature passed SB 375 which built upon AB 32 by connecting the reduction of greenhouse gas emissions from cars and light trucks to regional and local land use and transportation planning. SB 375 requires the California Air Resources Board (ARB) to establish greenhouse gas emission reduction targets for each region, and each

The APG also seeks to provide a comprehensive approach to climate adaptation that covers multiple aspects of community life that may be affected. Where the content of the APG overlaps with other guidance that focuses on a specific climate impact, a link is provided for those users who desire additional detail. The integration of APG guidance with climate adaptation guidance developed by other state agencies will help ensure that local and regional strategies are consistent with measures enacted by the state.

Because the most effective adaptation policy is based on local conditions, needs, and resources, the APG is not prescriptive in its approach. Instead, a decision-making framework is presented that provides straightforward, yet flexible, guidance for communities to begin taking direct actions in response to climate impacts. The steps presented include the interpretation of climate science for evaluation of local consequences, an examination of local vulnerability, and development of systematic rationale for reducing risks caused, or exacerbated, by climate change.

The APG is organized into three parts (see Figure 1):
**Part 1: Introduction and Framework.** This section is intended for all APG users. It explains the need for adaptation strategy development; identifies the steps in policy development; and presents the core considerations for vulnerability assessment and policy development. This component of the APG provides the foundation on which the other content items build.

**Part 2: Regions.** Because California has so many distinct environmental and socioeconomic settings, 10 climate impact regions were designated. More detailed guidance specific to the characteristics of each region is presented. Impacts are organized into eight climate impact sectors.

**Part 3: Adaptation Strategies.** The final part presents potential strategies to address the adaptation needs defined by APG users. It organizes adaptation policies by the same impact sectors introduced in Part 1. This listing includes examples from jurisdictions already pursuing adaptation strategies and considerations for tailoring potential strategies to local needs.

metropolitan planning organization (MPO) to create a Sustainable Communities Strategy (SCS) as part of the Regional Transportation Plan (RTP) to meet regional emissions reduction targets.

**SB 732 – Strategic Growth Council.** Also in 2008 the legislature passed SB 732 creating the Strategic Growth Council (SGC). The SGC is a cabinet-level committee tasked with coordinating the activities of state agencies to improve air and water quality, protect natural resource and agriculture lands, increase the availability of affordable housing, improve infrastructure systems; promote public health, and assist state and local entities in the planning of sustainable communities and meeting AB 32 goals. SB 732 gives the council authority to distribute planning grants and incentives to encourage the regional and local land use plans designed to promote water conservation, reduce automobile use and fuel consumption, encourage greater infill and compact development, protect natural resources and agricultural lands, and increase adaptability to climate change.

**General Plan Guidelines.** Climate change has also been recognized by the Governor's Office of Planning and Research (OPR) as a factor to be considered in preparation of local general plans. OPR is in the process of updating the 2003 General Plan Guidelines which provide guidance to cities and counties in the preparation of their local general plans. The next update will reflect legislative requirements enacted since 2003 and provide new guidance on addressing climate change, adaptation, and related issues.

**California Climate Adaptation Strategy and Related Adaptation Plans.** In 2009 the California Climate Adaptation Strategy (CAS) report was published by the California Natural Resources Agency. The CAS summarizes the best known science on climate change impacts in the state to assess vulnerability, and outlines possible solutions that can be implemented within and across state agencies to promote resiliency. This is part of an ongoing, evolving process to reduce California's vulnerability to climate impacts. In addition, several state departments have begun developing adaptation strategies and guidance (e.g. Keithley & Bleier, 2008; BCDC 2009; CEC, 2009; DWR, 2011).

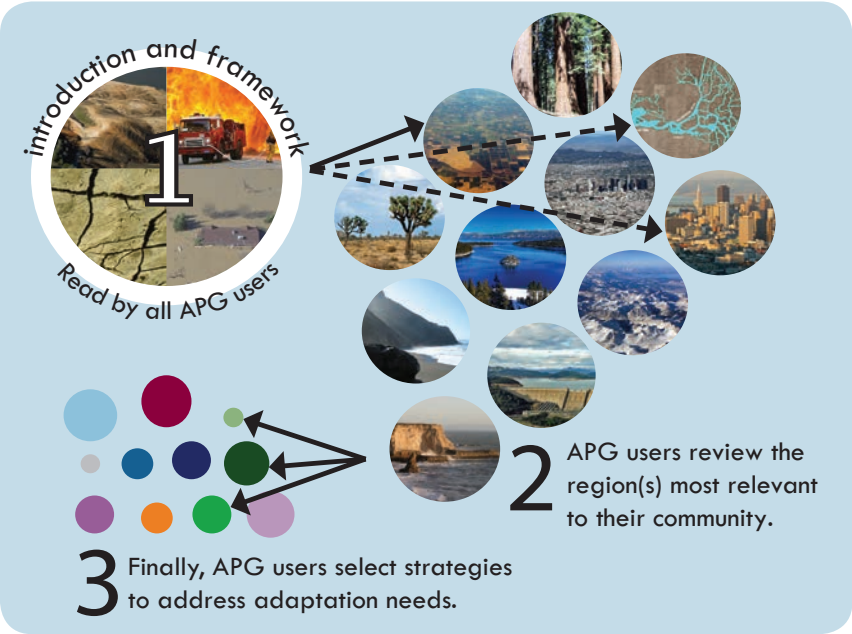



Figure 1. Illustration of how the three parts of the Adaptation Policy Guide (APG) work together.

## 1.2 The Importance of Community Action

Climate change impacts vary by geographic area. For example, northern parts of the state are projected to have a much larger change in wildfire occurrence than Southern California. Further contributing to the spatial disparity is that the consequences of the varied climate change impacts are often a product of community decisions and actions.

These factors give local and regional governments a critical role in addressing climate adaptation needs. Local and regional governments have direct influence on the physical setting of a community through land use and transportation planning, and they also control the provision of many basic services, from water to emergency response. In addition, it is local and regional governments that are most likely to understand the local social, cultural, and political setting of a region – an understanding that is necessary for developing strategies that not only successfully reduce vulnerability to climate change but also improve the long-term quality of life for residents.

Adaptation planning requires a commitment by jurisdictional leadership to take action, but it should not be approached as a distinct area of policy development. Success relies on the extent to which measures that reduce vulnerability also address other long-term community needs. In many cases, the most successful adaptation strategies are those that build on existing policies such as those found in a local hazard mitigation plan, the safety element of a general plan, an urban water management plan, or public health measures.

Many communities will need to communicate the necessity of adaptation policy development to their residents, advisory bodies, and elected officials. It can be difficult to invest resources to address a future need that is based on scientific climate models, each with an associated measure of uncertainty. When asked, community planners can address this concern by making two critical points: (1) Some of the risks associated

with climate planning, however unlikely, are too high to do nothing; and (2) Adaptation planning focuses on making a community more resilient and thus must address both current and future community needs.

### 1.2.1 Community Engagement

Community engagement around adaptation policies and strategies is essential to the adoption, equity, and efficacy of their implementation. Regarding adoption, local political processes require some level of consensus around approaches to climate change impacts, yet it is likely that "public opinion regarding climate change is divided and fluid" (Boswell et al, 2012, pg. 66). Local agencies cannot take for granted simple acceptance or agreement upon the appropriate measures for a community. Public engagement offers the opportunity to educate and build commitment and consensus among local decision-makers and community members. Communicating about climate change can be challenging. Many people still tend to view climate change impacts and solutions as global rather than local, meaning they may not understand the potential for local impacts or the efficacy of local approaches to adaptation. Communities also may not understand the "human" impacts of climate change, which may influence the relevance of these concerns for some (Maibach et al, 2011). There are a number of approaches to addressing these challenges, and several excellent resources for community engagement around climate change are listed in the next pages. A few of the most salient suggestions included in these resources are as follows:

- Localize the issues. Frame the issues in terms of local impacts and solutions.
- Clarify the human impacts of climate change along with other impacts.
- Emphasize the co-benefits of solutions and adaptation measures. For instance many actions taken to address and adapt to climate change (e.g. transit-oriented development that produces more walkable communities, urban greening) have positive benefits upon the health and livability of a community.
- Partner with other local agencies, NGO's, community organizations and groups and others and build on existing relationships with local communities.
- Utilize both traditional (newspapers and television) and relatively new forms of media (blogs and other forms of social media) to reach your audience.
- Consider the diversity of local groups within your community (e.g. consider special needs and cultural traditions) to maximize the diversity of groups participating. Local health departments may have pre-existing relationships with low-income and underrepresented communities and working with them can improve the inclusivity of the engagement process.
- Include people early in the process and through implementation.

**Additional Resources:**

- *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments*. (http://cses.washington.edu/db/pdfsnoveretalgb574.pdf): Chapter three of this guidebook steps one by one through the most common barriers to adaptation policy development identified by local and regional entities.
- California Department of Public Health [CDPH]. 2012. *Climate Action for Health: Integrating Public Health in Climate Action Planning.* Retrieved from http://www.cdph.ca.gov/programs/CCDPHP/Documents/CAPS_and_Health_Published3-22-12.pdf
- Local Governments for Sustainability [ICLEI]. 2012. *Community Engagement Tools*. Available at http://www.icleiusa.org/action-center/learn-from-others/small-communities-toolkit
- Boswell, M, Greve, A, & Seale, T. 2012. *Local Climate Action Planning*. Washington: Island Press.
- Maibach E, Nisbet M, & Weathers M. 2011. *Conveying the Human Implications of Climate Change: A Climate Change Communication Primer for Public Health Professionals.* Fairfax, VA: George Mason University Center for Climate Change Communication.

# 2.0 Adaptation Policy Development

Climate change has the potential to affect nearly all aspects of community life. As a result, the development of policy requires collaboration among a wide variety of department staff and community stakeholders. When a community commits to development of policy to address unavoidable climate impacts, a series of preparatory actions must be taken prior to engaging in vulnerability assessment and policy development.


**2.0 Adaptation Policy Development**
2.1 Committing to Take Action
2.2 Establishing a Climate Adaptation Team
2.3 Identifying Ways to Integrate Climate Adaptation into Local and Regional Policy
2.3.1 Local Hazard Mitigation
2.3.2 Climate Action Plans
2.4 Developing Climate Adaptation Policies


## 2.1 Committing to Take Action

The first step in addressing climate adaptation requires that a commitment be made by community leadership or advisory body to do so. The choice to pursue adaptation policy development can be made based on a variety of reasons that will likely vary by community. For some areas of California, climate change is already resulting in identifiable outcomes, from water shortage to shortened ski seasons to increased coastal flooding. Addressing current needs may drive a community to develop comprehensive adaptation policy in this case.

Other communities may pursue adaptation to assure long-term stability and quality of life. In these communities, adaptation policy may not be pursued due to currently adverse consequences, but rather to limit the disruption of those consequences projected in the future.

Regardless of reason, adaptation policy development requires a formal statement of commitment because comprehensive (multi-sector) adaptation policy relies on participation from a wide variety of staff and stakeholders. Moving forward with the planning process requires that jurisdictional support has been established. This can occur in a variety of ways, including issuing a proclamation, passing a resolution, or including adaptation as a jurisdictional goal in a capital improvement plan or similar guidance.

## 2.2 Establishing a Climate Adaptation Team

The most important step in preparing to develop climate policy establishing a climate adaptation team. A climate adaptation team allows for communication and collaboration between departments and with stakeholders. This team can take multiple forms such as a task force, committee, or workshop series. Communities should determine the best approach to meet local needs. This determination can be based on duration of the policy development period, the level of local commitment to the process, and availability of staff.

Adaptation policy development requires information and feedback from staff members most familiar with each aspect of community function potentially vulnerable to climate impacts. Assessing vulnerability requires an evaluation of secondary impacts of climate change, which have the potential to involve local conditions as varied as ecosystem health, economic viability, infrastructure maintenance, emergency response, and public health. In addition to evaluating potential impact, the climate adaptation team is critical to assessing the effectiveness of existing policies and programs in responding to the projected climate changes.

The critical members of the climate adaptation team will vary by community. Categories of expertise that should be considered when constructing an adaptation team include the following:

- Long-range planning or community development
- Emergency response and natural hazards planning
- Economic development
- Parks and open space
- Transportation or engineering
- Utilities (water, wastewater, etc.)
- Administration/finance
- Chamber of commerce
- Public health
- Social services
- Local non-governmental organizations (NGOs) (environmental, social, etc)
- Professional organizations (agricultural, fisheries, communications, etc.)

Strong community commitment to adaptation policy development allows for establishment of a robust adaptation team. A team that includes the needed expertise in a given community requires staff time from several departments and community stakeholders.

Establishment of an adaptation team requires that the department or agency leading the effort carefully develop a team work plan that clearly demonstrates the importance and relevance of the efforts of the adaptation team. This may begin with educating the team on climate risks and the steps in adaptation process. This is why a lecture series is identified as one means of establishing a collaborative team.

The sections detailing vulnerability assessment and policy development (sections 4.0 and 5.0) describe the steps and information necessary for adaptation policy development. The adaptation team will need to be comprised of the local staff and community stakeholders necessary to accurately complete these steps.

## 2.3 Identifying Ways to Integrate Climate Adaptation into Local & Regional Policy

One of the largest challenges to climate adaptation policy development is the diversity in the potential impacts, which include public health, economic vitality, ecosystem health, water supply, and natural hazards. Fortunately, many existing local and regional plans already address some of these impacts, meaning that communities are likely to have a good idea of the types of strategies likely to be most effective. In some cases, developing adaptation policy can simply involve bolstering existing policies through the periodic plan update process.

The manner in which climate adaptation strategies are integrated into policy documents can vary based on local adaptation needs and context. Adaptation policies can be integrated into local policy in a variety of ways, from development of a stand-alone climate adaptation plan to integration of policies into any number of local policy documents. The ultimate goal should be for climate adaptation to be included as one consideration in all local and regional policy-making processes.

A stand-alone climate adaptation plan can set a comprehensive adaptation strategy for a jurisdiction that integrates the many distinct areas of adaptation policy. With a stand-alone plan, all other plans and programs would slowly be adjusted to be consistent through periodic updates as they would normally occur.

Conversely, individual adaptation policies can be developed and integrated directly into the plans, policies, or programs most appropriate for implementation. The plans or policies that can be used to implement adaptation strategies include the general plan, stormwater plan, urban water management plan, local hazard mitigation plans, climate action plans, zoning code, capital improvement plan, public health measures, and

many other local or regional policy documents.
While many local plans may include policies that meet adaptation goals, two types of plans warrant further discussion: (1) local hazard mitigation plans, because of the high level of overlap with adaptation planning; and (2) climate action plans, because staff will need to communicate to community members and decision-makers how adaptation relates to greenhouse gas reduction, the other broad policy aim related to climate change.

### 2.3.1 Local Hazard Mitigation

Climate change has the potential to alter the type, frequency, and severity of natural hazards. As a result, existing hazards plans are a primary indicator of community capacity to adapt to climate change and offer lessons for adaption strategy development. There are many similarities between the process of developing a local hazard mitigation plan and adaptation policy. Both are based on a careful evaluation of vulnerability and associated risk, inventorying community assets, and estimating the potential consequences.

Adaptation policy overlaps with hazards planning in addressing risks such as flooding, fire, and landslide. However, climate change alters the nature of the hazard, which means that the manner in which hazard planning has been conducted in the past may not be adequate to address the impacts that will result from climate change in the future. Hazard planning relies on the historic frequency of events to predict future needs. The result of climate change is that history alone is no longer an adequate predictor of future needs. The frequency and severity of natural hazards is likely to change over time. This change does not invalidate natural hazard planning tools, but it does mean that these tools require adjustment and updating to accommodate the evolving nature of the hazards being addressed.

Climate adaptation shwould be included in hazards policy development (e.g., general plan safety elements or local hazard mitigation plans), but the process of predicting future risk must be adjusted to accommodate climate projections. As a result, adaptation planning must be coordinated with other local planning efforts, particularly hazards planning. The vulnerability and risk assessment conducted as part of an adaptation policy development effort should also be used to inform local hazards policy, as well as land use planning.

### 2.3.2 Climate Action Plans

Local policy documents can address climate change by establishing goals for greenhouse gas (GHG) emissions reduction and adaptation. These two goals should be pursued in parallel. While they are complementary in most ways, there is potential for conflict (Moser, 2012; see Figure 2). For example, a cooling center that provides relief for community members during extreme heat events may rely on air conditioning. Depending on the source of electricity this can increase GHG emissions. In addition, even when both goals are being met by a single strategy, the reasoning that led to the strategy will be different. For example, a tree planting program will aid in sequestering carbon, a GHG reduction benefit, and help alleviate the effect of heat, an adaptation need.

The challenge for local jurisdictions is to evaluate each strategy relative to local need. In a dense urban area where extreme heat also carries risks of decreased air quality and increased heat-related health consequences, a tree-planting program alone may not be enough to address the threat posed by climate change on its own. For each strategy considered to address a climate adaptation need, GHG reduction should be viewed as a desirable co-benefit but should not supersede the primary aim of improving community resilience in the face of unavoidable climate impacts.

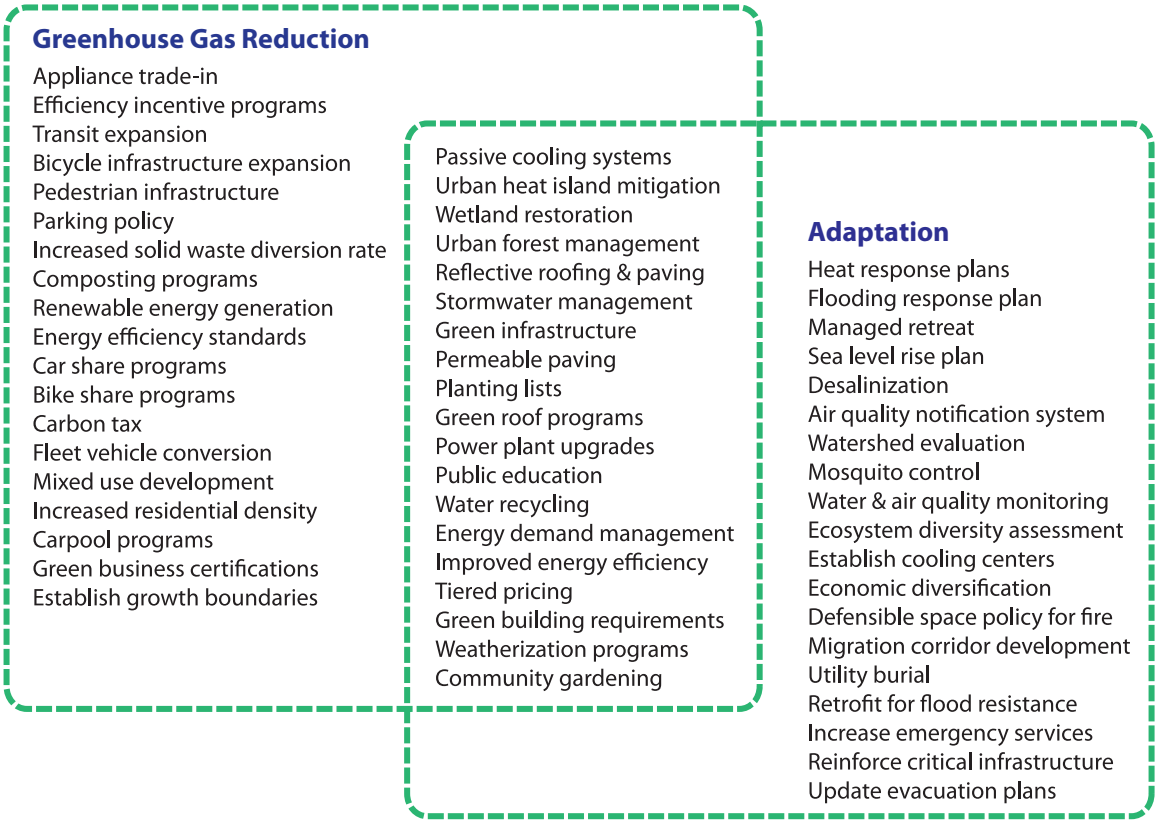



Figure 2. Illustration of the overlap between greenhouse gas emissions reduction measures and climate change adaptation strategies.
[Moser, 2012; Boswell, Greve, and Seale, 2012]

## 2.4 Developing Climate Adaptation Policies

The development of climate adaptation policies poses several challenges to local and regional policy-makers, including the evolving nature of the climate science, the inherent uncertainty in projections, and the breadth of community assets potentially affected by climate change. Effectively navigating this complexity to develop climate adaptation strategies requires a framework that allows for decisions to be made in the face of uncertainty and assures that local needs and characteristics are considered. Adaptation strategies seek to reduce vulnerability to the projected changes and increase the local capacity to adapt (Turner et al., 2003).

Community development of policy to address climate change impacts follows a sequence of steps: (1) assessing exposure to climate change impacts; (2) assessing community sensitivity to the exposure; (3) assessing potential impacts; (4) evaluating existing community capacity to adapt to anticipated impacts; (5) evaluating risk and onset, meaning the certainty of the projections and speed at which they may occur; (6) setting priorities for adaptation needs; (7) identifying strategies; (8) evaluating and setting priorities for strategies; and (9) establishing phasing and implementation. The nine steps can be arranged in sequence, with the first five making up a vulnerability assessment (see Figure 3). The vulnerability assessment serves to identify the adaptation needs of a community. Based on these needs, strategies can be devised and implemented.

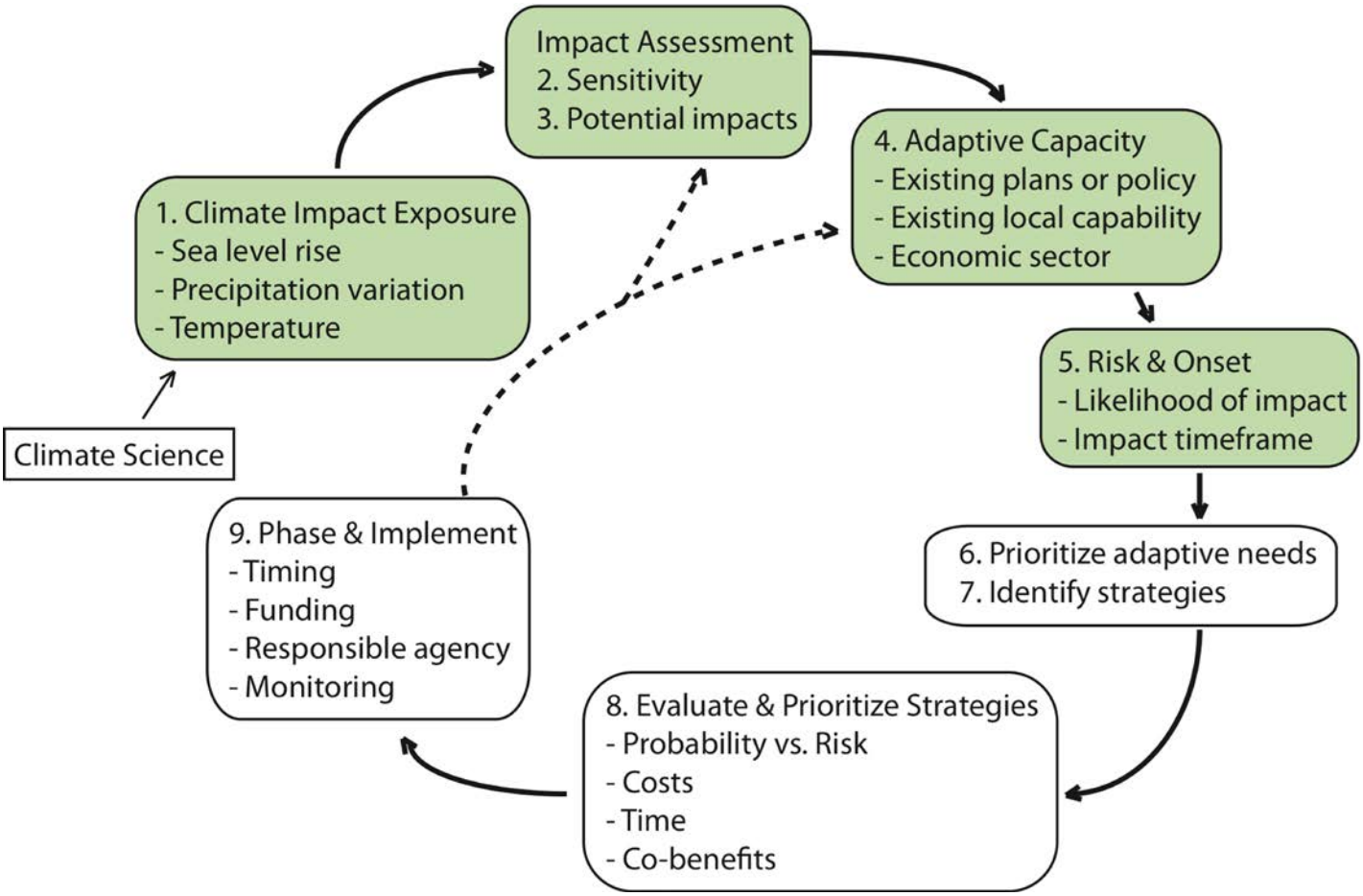



Figure 3. Steps in adaptation policy development. The shaded boxes are all considered part of local vulnerability assessment.
[Adapted from Boswell, Greve, and Seale, 2012]

# 3.0 Climate Change in California

**3.0 Climate Change in California**
3.1 Current Climate Change Projections
3.1.1 Temperature
3.1.2 Precipitation
3.1.3 Sea Level Rise
3.1.4 Ocean Acidification
3.1.5 Wind
3.2 Estimating Climate Change Impacts: The Cal-Adapt Online Tool
3.2.1 Emissions Scenarios Used by Cal-Adapt
3.2.2 Climate Models Used by Cal-Adapt
3.3 Secondary Impacts by Sector
3.3.1 Equity, Health, and Socio-economic Impacts
3.3.2 Ocean and Coastal Resources
3.3.3 Water Management
3.3.4 Biodiversity and Habitat
3.3.5 Forest and Rangeland
3.3.6 Agriculture
3.3.7 Transportation and Energy Infrastructure

The State of California has pursued research focused on climate change since the late 1980s. This work has yielded climate change projections and estimates of associated impacts that have been tailored specifically to California (e.g., CNRA, 2009; Moser et al., 2009). These data serve as the technical basis for adaptation policy development.

Climate change directly affects a limited number of environmental conditions: temperature, precipitation, sea level, ocean acidification, and wind associated with storm events. Resulting from these direct impacts are a wide range of secondary impacts. Communities must assess their vulnerability to both classes of impacts.

## 3.1 Direct Impacts of Climate Change

An assessment of a community's vulnerability to climate change begins with an understanding of local exposure to direct impacts. The range of direct impacts anticipated for California is summarized below.

### 3.1.1 Temperature

Climate change alters seasonal temperature patterns. Effects can include changes in average temperature, the timing of seasons, and the degree of cooling that occurs in the evening. In addition to new seasonal temperature patterns, extreme events such as heat waves are projected to occur more frequently and/or last for longer periods of time. Changes in average temperature, when evaluated on large scales (state, national, or global), have a fairly high level of certainty with consistency among various models (IPCC, 2007).

In California, temperature increases are expected to be more pronounced in the summer and in inland areas. Heat waves are projected to increase not only in frequency but in spatial extent (CNRA, 2009). The degree of change experienced partially depends on global GHG emissions and atmospheric concentrations; by 2050, however, temperature increases between 1.8 to 5.4 °F are projected under both emissions scenarios examined by the State of California (CNRA, 2009).

At the local level, specific changes to seasonal temperature profiles are more difficult to project precisely, due to the interaction with other factors such as cloud cover, moisture presence, topography, and regional air mass circulation than can lead to inversions (IPCC, 2007; Iacobellis et al., 2009).

### 3.1.2 Precipitation

Similar to temperature, seasonal precipitation patterns, including the timing, intensity, and form of precipitation, are projected to change. Precipitation differs from temperature in that it has greater spatial variability and is more difficult to predict. Climate models demonstrate less consistency in projecting the amount and timing of precipitation and rain vs. snowfall patterns (IPCC, 2007; CNRA, 2009).

Despite this variability, most models project reduced precipitation in California as a whole. Northern California is projected to have a 12- to 35-percent decrease in precipitation. Mountainous regions are expected to see precipitation fall more frequently as rain instead of snow. These changes have implications for state water supply. Increased likelihood of drought, punctuated by occasional intense rainfall, is also expected (CNRA, 2009). Changes in precipitation and temperature interact. Higher temperatures increase evaporation, which can result in a drier climate. In addition, temperature variation can result in earlier and faster snowmelt (CNRA, 2009).

### 3.1.3 Sea Level Rise

Sea level has risen about seven inches over the last century due to global melting of land-based ice and thermal expansion (i.e., water expanding as it warms) (IPCC, 2007; CNRA, 2009). Climate change projections estimate a 55-inch (1.4-meter) rise in sea level by 2100 (CNRA, 2009). This projected sea level rise includes global changes in surface runoff but does not include rapid melting of continental ice sheets or thermal expansion of marine waters. As with other climate impacts, there is variation but general agreement among the various models (IPCC, 2007). This agreement provides a increased certainty for communities that projected sea level rise will occur. As a result, communities facing projected impacts due to sea level rise can feel greater urgency and confidence in taking action.

### 3.1.4 Ocean Acidification

Atmospheric carbon dioxide is absorbed by the ocean. As a result, the concentration of carbon dioxide in oceans is increasing in parallel with atmospheric concentrations. Increased carbon dioxide lowers the pH of ocean water. Since the pre-industrial era, ocean pH has decreased 0.1 unit from 8.2 to 8.1 and is expected to decrease by another 0.3 to 0.4 by 2100 (Orr, 2005; Huari et al., 2009). This change in ocean pH affects the overall ocean chemistry (IPCC 2007). This is a rapidly growing and evolving area of investigation. Evidence indicates that a more acidic ocean water can have detrimental effects on marine life, particularly organisms with a calcium carbonate shell (Orr et al., 2005; IPCC 2007; Huari et al., 2009). Communities reliant on marine ecosystems, particularly organisms such as oysters that likely to be affected by changing ocean acidity, should pay close attention to scientific findings as they come available.

### 3.1.5 Wind

Put simply, wind results from temperature difference in air masses that create a pressure differential. Climate change, which is warming most marine and land surfaces of the globe, will influence wind speeds and pattern from the jet stream to the frequency of extreme events (IPCC, 2007).

How climate change is likely to affect wind in California is unclear. Wind is a product of circulation patterns, surface energy, and topography. As a result, there is a great deal of variability among modeled outcomes (Rasmusson, Holloway, and Nemet, 2011). Despite uncertainty, wind, when combined with other direct impacts, can pose risks to California communities. For example, wind in combination with extreme high tides can result in severe coastal storms. Similarly, wind in combination with hot, dry conditions can worsen fire risk.

## 3.2 Estimating Climate Change Impacts: The Cal-Adapt Online Tool

Estimating the range of projected climate impacts on a local or regional level can be challenging for jurisdictions because most climate change projections have a coarse spatial scale, less useful for local policy decisions. Cal-Adapt is an online tool intended to support local efforts by providing increased spatial resolution and an ability to quickly evaluate several climate impacts for any location in California. This tool resulted from the recommendation by the 2009 California Climate Adaptation Strategy (p.9) to "synthesize existing California climate change scenarios and climate impact research and to encourage its use in a way that is beneficial for local decision-makers."

Cal-Adapt provides a convenient and easy-to-use tool for communities to conduct a preliminary assessment of climate change exposure. It should be one of the first steps taken when engaging in an adaptation policy development process. It can accessed at Cal-Adapt.org.

Cal-Adapt uses two greenhouse gas emissions scenarios and four climate models to produce maps and graphs that display a selection of direct and secondary climate change impacts: temperature, precipitation, sea level rise, wildfire risk, and snowpack. The multiple emissions scenarios and models allow jurisdictions to view the range of projected climate impacts.

### 3.2.1 Emissions Scenarios Used by Cal-Adapt

All of the climate tools presented in Cal-Adapt have the option of selecting GHG emissions scenarios independent of climate models. These scenarios each reflect different ranges of outcomes for global development and population growth. Cal-Adapt uses two GHG emissions scenarios—referenced as A2 and B1—that were created by the Intergovernmental Panel on Climate Change (IPCC). Each scenario leads to a projection of possible emissions levels based on population growth rate, economic development, and other factors. Ultimately, the effect on climate change depends on the amount and the rate of accumulation of heat-trapping gases in the atmosphere that these scenarios suggest. Communities using Cal-Adapt should understand the assumptions that each emissions scenario represents. This understanding will allow a community to make an informed decision about the scenario they choose project future climate change.

**Medium-High Emissions Scenario (A2).** The medium-high emissions scenario projects continuous population growth and uneven economic and technological growth. Fertility rates decline relatively slowly in this scenario, which makes this scenario's projected global population (15 billion by 2100) the highest. The income gap between now-industrialized and developing parts of the world does not narrow, and global per-capita income is lower relative to other scenarios. Heat-trapping emissions increase through the 21st century as atmospheric carbon dioxide concentration approximately triples, relative to pre-industrial levels, by the year 2100. This is mostly due to relatively weak global environmental concerns, with attempts to bring pollution under control being made regionally and locally, rather than internationally (CEC, 2011; IPCC, 2000).

**Lower Emissions Scenario (B1).** The lower emissions scenario projects a world with high economic growth and a global population that peaks by mid-century and then declines. The element central to this scenario is a global approach to developing sustainably, merged with a high level of economic and social consciousness. Therefore, much of the economic gain in this scenario would be reinvested in improved efficiency of resource use, equity, social institutions, and environmental protection. Technological changes, as well as increased government, public, media, and businesses awareness of the environmental and social aspects of development, play important roles. The B1 scenario assumes a rapid shift toward less fossil fuel-intensive industries and introduction of clean and resource-efficient technologies. Global population would reach nine billion by 2050 and decline to seven billion by the end of

the century. Heat-trapping emissions would peak about mid-century and then decline; carbon dioxide concentration would approximately double, relative to pre-industrial levels, by the year 2100. (CEC, 2011; IPCC, 2000)

**Which Scenario Should Decision-Makers Use?** Of the two options provided by Cal-Adapt, the A2 scenario is the more realistic choice for decision-makers to use for climate adaptation planning. The B1 scenario is optimistic in the high level of international cooperation assumed. This cooperation would necessitate sweeping political and socio-economic change on a global magnitude that is as yet unprecedented. The roughly two billion-person decline in population over the last half of the century is also reliant on broad assumptions of low mortality and low fertility. Generally, the B1 scenario might be most appropriately viewed as a version of a "best case" or "policy" scenario for emissions, while A2 is more of a status quo scenario incorporating incremental improvements. However, it is impossible to say which of the scenarios is more statistically likely. The IPCC has not assigned probabilities to any of its scenarios, and therefore other possibilities, with lower or higher emissions, may occur (CNRA, 2009, p.15). Nevertheless, as the 2009 California Climate Adaptation Strategy (p.15) notes, "the world has followed a 'business as usual' emissions pathway, which most closely resembles the A2 scenario." From a pragmatic standpoint, then, the A2 scenario would be the better choice, as it seems to reflect real-world conditions and does not rely upon a fundamental global policy shift as the B1 scenario does.

## 3.3 Secondary Impacts by Sector

The direct climate impacts (temperature, precipitation, sea level rise, ocean acidification, and wind) affect a wide range of community assets, populations, and basic functions. These impacts have been separated into a series of "sectors" that serve as the organizing framework for the community assessment of climate adaptation needs. The seven identified sectors are as follows: (1) equity, health, and socioeconomic Impacts; (2) ocean and coastal resources; (3) water management; (4) forest and rangeland; (5) biodiversity and habitat; (6) agriculture; and (7) transportation and energy infrastructure.

This section summarizes the issues facing each sector and some of the changes that may be experienced by California communities. Following the discussion of vulnerability assessment and policy development in Sections 4.0 and 5.0, these sectors – including the primary steps in sector-specific vulnerability assessment – are reviewed in greater detail in Section 6.0

### 3.3.1 Equity, Health, and Socio-economic Impacts

This sector reviews the equity, public health and socio-economic impacts of heat events, average temperature change, intense rainstorms, reduced air quality, and wildfires on people, focusing on groups who are most sensitive to these impacts because of both intrinsic (e.g. age, race/ethnicity, gender) and extrinsic (e.g. financial resources, knowledge, language, occupation) factors. Equity concerns are based on the idea that some populations bear a disproportionate amount of the climate change effects (Morello-Frosch et al, 2009a). Public health focuses on the health impacts resulting from the direct effects of climate change (e.g. rising temperature, increasing climate variability, increased rainfall, and drought), as well as its indirect effects (e.g. sewage overflows resulting from flooding, contaminated ground water from salt water intrusion, and vector-borne diseases from changes in precipitation) (Maibach et al, 2009). Climate change will impact economic growth, particularly specific industries such as agriculture or tourism. These changes increase the vulnerability of local populations that rely on these industries.

### 3.3.2 Ocean and Coastal Resources

Changes such as sea level rise, intensification of coastal storms, and ocean acidification may affect ocean and coastal resources. Potential environmental impacts of these changes include coastal flooding/inundation, loss of coastal ecosystems, coastal erosion, shifts in ocean conditions (pH, salinity, etc.), and saltwater intrusion. The combination of sea level rise and possible intensification of coastal storms presents a threat to coastal development and infrastructure. Climate-related changes to marine ecosystems may result in altered population and ranges of fish species, which affect productivity and the commercial fishing industry. With 85 percent of California's residents living in coastal counties, sea level rise could potentially damage whole communities while also affecting tourism, the provision of basic services (e.g. wastewater treatment), and recreational economies.

### 3.3.3 Water Management

Climate change may result in flooding and reduced water supply in communities. Although the scientific evidence regarding increased flooding related to climate change remains uncertain, it is prudent for communities to recognize that changes to precipitation regimes and rate/timing of snowmelt may affect flooding. The water supply includes both surface water and groundwater, along with the infrastructure necessary for management, conveyance, and treatment. Water supply is expected to be effected in areas that experience less precipitation and areas dependent on snowpack.

### 3.3.4 Biodiversity and Habitat

Climate change may affect terrestrial and freshwater aquatic habitats and the species that depend on them. California is a unique hotspot of biodiversity (CEC, 2009). Changes in the seasonal patterns of temperature, precipitation, and fire due to climate change can dramatically alter ecosystems that provide habitats for California's native species. These impacts can result in species loss, increased invasive species' ranges, loss of ecosystem functions, and changes in growing ranges for vegetation.

Reduced rain and changes in the season distribution of rainfall may reduce low flows in streams and rivers, which in turn would have consequences for aquatic ecosystems. In addition to altered flow levels that influence aquatic food webs, water temperature may increase, which could affect water quality and the health of aquatic species, particularly threatened or endangered species. For species reliant on aquatic systems that have limited extents, such as vernal pools, wetlands, and lakes, there is limited opportunity to escape when habitat conditions change due to fluctuating water levels and temperatures.

### 3.3.5 Forest and Rangeland

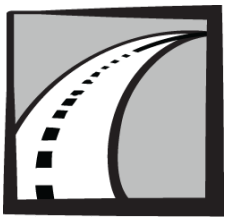
Climate can have an influence on wildfire and forest health. In forest ecosystems, climate change can alter the species mix, moisture and fuel load, and number of wildfire ignitions. Changes in species mix and moisture due to dry periods can alter wildfire timing (seasonality and frequency), spatial distribution (fire size and complexity), and

magnitude (intensity, severity, and type). These changes in wildfire character are related to a range of forest health indicators such as growth rate, invasive species, erosion, and nutrient loss.

In addition, climate change and fire regime together can result in conversions from forest to shrub to grassland. Each of these ecosystem types has a distinct fire frequency and behavior. It is therefore important to understand the manner in which historic fire regimes may be altered due to climate change and the community resources that may be vulnerable as a result.

### 3.3.6 Agriculture

The threats posed by climate change have the potential to influence crop and livestock productivity. These changes can have far-reaching impacts, from altering the local economy to affecting food supply. Climate change can affect agriculture through extreme events (e.g., flooding, fire) that result in large losses over shorter durations, or through more subtle impacts such as changes in annual temperature and precipitation patterns that influence growing seasons or livestock health. These impacts also have the potential to result in a range of associated consequences such as altered pest and weed ranges, reduced air quality, and reduced farm worker safety (heat and air quality). This is critically important in California; as the leading producer of agricultural goods in the United States, the state's agricultural economy is valued at billions of dollars annually. Changes in agriculture therefore could be detrimental to the economic viability of many areas of the state.



### 3.3.7. Transportation and Energy Infrastructure

Transportation includes roadways, airports, marine ports, and shipping routes. Energy infrastructure includes both power plants and transmission systems. Transportation and energy infrastructure can be affected by climate change through direct disruption of service due to fire, inundation, or landslide; changes in efficiency and maintenance requirements; and increased demand. Disruption of transportation systems has the potential to be detrimental to the economic vitality of the communities relying on them for delivery of goods and services. Energy is critical for communities coping with the impacts of climate change, particularly for powering pumps needed to deliver water and for interior cooling in the face of extreme heat.

# 4.0 Vulnerability Assessment – Adaptation Policy Development Steps 1-5

**4.0 Vulnerability Assessment – Adaptation Policy Development Steps 1-5**
4.1 Step 1: Assessing Climate Change Exposure
4.2 Step 2: Assessing Sensitivity
4.3 Step 3: Assessing Potential Impacts
4.4 Step 4: Evaluating Adaptive Capacity
4.5 Step 5: Evaluating Risk & Impact Onset
4.5.1: Risk/Uncertainty
4.5.2: Timeframes
4.5.3: Capacity to Respond

Climate vulnerability assessment is a method for determining the potential impacts of climate change on community assets and populations. The severity of these impacts and the community's ability to respond will determine how these impacts affect a community's health, economy, ecosystems, and socio-cultural stability. Communities that understand these impacts can prepare climate adaptation policies and programs to increase resilience to climate change. Section 6.0, Sectors, steps through vulnerability assessment for each of the sectors that may experience climate change impacts.

This section outlines a process for conducting a climate vulnerability assessment. Vulnerability assessment involves the first five steps in climate adaptation policy development discussed in Section 2.0 (see Figure 3):

1. Climate Change Exposure: Identify what types of climate change effects the community will be exposed to (using Cal-Adapt).
2. Sector Sensitivity: Identify the key assets in each sector (and their functions) relevant to the community that are potentially susceptible to each climate change exposure.
3. Potential Impacts: Analyze how the climate change exposure will affect the community sectors (impacts).
4. Adaptive Capacity: Evaluate the community's current ability to adapt to the projected impacts.
5. Risk and Onset: Adjust the impact assessment to account for uncertainty, timing, and adaptive capacity.

Another way to look at the five steps is to consider how they relate to two main stages in vulnerability assessment, which are illustrated in Figure 4. The first stage is to use the analysis of climate change exposure (Step 1) and sector sensitivity (Step 2) to identify the potential impacts of climate change on community assets and populations (Step 3). The second stage is to evaluate how the potential impacts (Step 3) combine with adaptive capacity (Step 4) and risk/onset (Step 5) to determine the community's overall vulnerability.

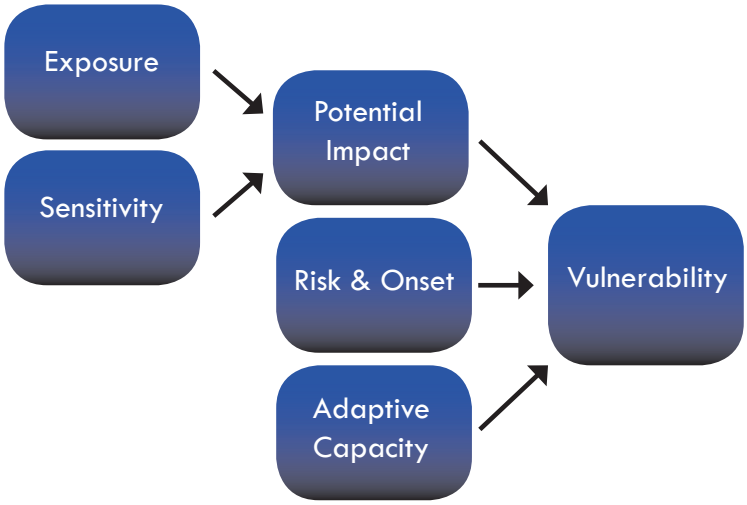



FIgure 4. Steps in Climate Change Vulnerability Assessment

Climate vulnerability assessment requires significant data collection and analysis. Some of the data may be well documented for the community and some may exist only in the collective knowledge of community experts. The analysts conducting the climate vulnerability assessment will need to identify data needs and consider whether to create a technical group of experts to create a robust assessment; this is a critical role for the climate adaptation team.

**Additional Resources**

- FEMA. (2001). *Understanding Your Risks: Identifying Hazards And Estimating Losses.* FEMA 386-2.
Retrieved from: http://www.fema.gov/library/viewRecord.do?id=1880
This "how to" guide provides step-by-step guidance for vulnerability assessment with respect to hazards. Many of these steps are shared by adaptation planning.

- *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments*
Retrieved from: http://cses.washington.edu/db/pdf/snoveretalgb574.pdf
Chapter 8 of this guidebook includes a vulnerability assessment. It uses slightly different terms, but the general approach is similar.

## 4.1 Step 1: Assessing Climate Change Exposure

Climate change exposure is the forecasted effect of climate change in a region. For example, communities along the coast are forecasted to experience rising sea levels that will increase coastal erosion, flooding, and saltwater intrusion. The effects of climate change are forecasted using global scale models and then down-scaled to regions to create potential future scenarios of climate change. Down-scaling adds additional uncertainty to these estimates. The role of the information on probability is addressed in Step 5.

In California, Cal-Adapt assembles a variety of data sources to show climate change scenarios for California at the regional level; the data are not fine-grained enough to show local-level impacts, nor are the downscaled models sufficiently robust to show the scenarios with certainty. Therefore, all users of the tools should understand that the scenarios they are working with contain a level of uncertainty and become increasingly limited in usefulness as the geographic extent decreases.

The following three steps are used to estimate regional climate change exposure:

1. Use the online Cal-Adapt tool (http://cal-adapt.org/) to determine local exposures for primary climate change factors (use high emissions scenario):
   a. Sea-level rise: Identify areas of the community that are currently subject to coastal flooding (100-year flood) and areas potentially subject to the 55-inch rise forecasted for 2100.
   b. Precipitation: Identify the current annual precipitation and the forecasted change over time to 2090.
   c. Temperature: Identify the current average seasonal temperatures and the forecasted change over time to 2100.
2. Use the online Cal-Adapt tool (http://cal-adapt.org/) to determine local exposures for secondary climate change factors:
   a. Wildfire
   b. Snow pack

3. Estimate other secondary impacts using Table 1. Since Cal-Adapt provides no other data on secondary impacts, users should estimate these using the rubric in Table 1. The table lists additional secondary impacts . Whether these would occur is then based on whether the "driver" (i.e., one of the primary climate change factors) is occurring based on analysis in Step 1. For example, if the community will experience temperature change, then there is a high probability it will experience increased heat waves. Table 2 provides a guide for estimating the level of probability that certain key drivers will occur.

Table 1. Secondary Impact Estimation

| Secondary Exposure | Driver Occurs? | Certainty* |
|---|---|---|
| Inundation/long-term waterline change | ↑ sea-level | High |
| Extreme high tide | ↑ sea level | High |
| Coastal erosion | ↑ sea level | High |
| Salt water intrusion | ↑ sea level | High |
| Changed seasonal patterns | ↑ or ↓precipitation-and/or-↑ or ↓ temperature | Medium |
| Heat wave | ↑ temperature | High |
| Intense rainstorms | ↑ temperature-and/or- ↑ or ↓precipitation | Medium |
| Landslide | ↑ wildfire-and/or- ↑ precipitation | Medium |
| Drought | ↑ temperature-and/or- ↓precipitation | Medium |
| Wildfire | Use Cal-Adapt | Medium |
| Snowpack | Use Cal-Adapt | High |

Estimated based on most conservative driver from Table 2.
Source: IPCC. 2007. WG1 Physical Science Basis, Section 10 & 11.

Table 2: Probability Based on Global Models

| Driver | % Prob. Of Driver (IPCC) | Certainty |
|---|---|---|
| Temperature change | > 90% probability | High |
| Precipitation change | > 66% probability | Medium |
| Sea-level rise | >90% probability | High |
| Snow season and depth change | > 90% probability | High |

Source: IPCC. 2007. WG1 Physical Science Basis, Section 10 & 11.

* Estimated based on most conservative driver from Table 2.

## 4.2 Step 2: Assessing Sensitivity

Sensitivity assessment is a systematic evaluation to identify community assets, functions, and populations that may be affected by the projected exposure to climate impacts. The primary categories for this evaluation are described below (FEMA, 2001). The lists below provide a checklist of potential points of sensitivity that can aid in comprehensively addressing potential impacts.

**2. ASSETS**

Residential
Commercial
Industrial
Government
Institutional (schools, churches, hospitals, prisons, etc.)
Parks & open space
Recreational facilities
Infrastructure
Water treatment plant and delivery infrastructure
Wastewater treatment plant and collection infrastructure

**1. FUNCTIONS**

Government continuity
Water/sewer/solid waste Energy delivery
Emergency services
Public safety
Public health
Emotional and mental health
Business continuity
Housing access
Employment and job access
Food security
Mobility/transportation/access
Quality of life
Social services
Ecological function
Tourism
Recreation
Agriculture, forest, and fishery productivity
Industrial operations

**3. POPULATIONS**

Seniors
Children
Individuals with disabilities
Individuals with compromised immune systems
Individuals without access to cars
Non-white communities
Low-income communities
Renters

For each climate impact sector, an evaluation of sensitivity should be conducted. Not all categories of potential sensitivity will be associated with an individual sector, but this list assures that less obvious secondary impacts are identified. This step focuses solely on identifying assets, function, and populations sensitive to climate change. The next step evaluates the extent of the sensitivity.

- Identify **critical facilities** that are important to your community (five types):
  - **Essential Facilities**, including hospitals and other medical facilities, police and fire stations, emergency operations centers and evacuation shelters, and schools. These facilities are essential to the health and welfare of the whole population and are especially important following hazard events. The potential consequences of losing them are so great that they should be carefully inventoried. Be sure to consider not only their structural integrity and content value, but also the effects on the interruption of their functions, because the vulnerability is based on the service they provide rather than simply their physical aspects.
  - **Transportation Systems**, including airways (airports, heliports, highways); bridges; tunnels; road beds; overpasses; transfer centers; railways (trackage, tunnels, bridges, rail yards, depots); and waterways (canals, locks, seaports, ferries, harbors, drydocks, piers).
  - **Lifeline Utility Systems**, including potable water, wastewater, oil, natural gas, electric power and communication systems.
  - **High Potential Loss Facilities**, i.e., facilities that would have a high loss associated with them, such as nuclear power plants, dams, and military installations.

- Hazardous Material Facilities, including facilities housing industrial/hazardous materials, such as corrosives, explosives, flammable materials, radioactive materials, and toxins.

- Identify **vulnerable populations** such as non-English-speaking people or elderly people who may require special response assistance or special medical care after a disaster.
- Identify **economic elements** such as major employers and financial centers in your jurisdiction that could affect the local or regional economy if significantly disrupted.
- Identify **areas of special considerations** such as areas of high-density residential or commercial development that, if damaged, could result in high death tolls and injury rates.
- Identify **historic, cultural, and natural resource areas** including areas that may be identified and protected under state or federal law.
- Identify **other important facilities** that help ensure a full recovery of your community or state following a hazard event. These would include government functions, major employers, banks, and certain commercial establishments, such as grocery stores, hardware stores, and gas stations.

## 4.3 Step 3: Identifying Potential Impacts

Assessing potential impacts can be time-consuming and difficult depending on the desired level of detail. It also is closely related to the following step of evaluating adaptive capacity; vulnerability is determined by assessing the degree to which an identified point of sensitivity will affect a community (Step 3) and evaluating existing tools to address this impact (Step 4)

The Federal Emergency Management Agency (FEMA), in its "how-to" guides, establishes methods for creating detailed assessments of hazard impacts (FEMA, 2001). Although these could be applied to climate and climate-related hazards, the level of detail is high. Moreover, the uncertainty of climate scenarios lessens the usefulness of this approach. Given that climate change exposures at the community scale are inherently uncertain, it is recommended that communities conduct a qualitative assessment that describes the potential impact based on the exposure.

Accurately describing potential impacts will rely on input from the climate adaptation team (staff members and stakeholders most familiar with each the affected sectors). What qualifies as a high level of impact or disruption to a community should be determined by staff and stakeholders. The same impact can have very different meaning in different communities. Factors to consider in defining these terms should include the spatial and temporal extent of the impact, the degree to which it yields permanent or reversible consequences and/or endangers local population (physical safety, health, etc.), and the extent to which the impact would disrupt typical community function, such as provision of services or economic continuity.

The climate adaptation can help assess the potential impacts of exposing the sectors to climate change by developing general descriptive scenarios. Each description should include the following for each identified point of sensitivity:

a. The temporal extent of the impact.
b. The spatial extent of the impact.
c. The permanence of the impact
d. The level of disruption to normal community function.

## 4.4 Step 4: Evaluating Adaptive Capacity

Adaptive capacity is the current ability of the community or asset to adapt to or be resilient to potential impacts. Higher adaptive capacity or resilience may lower the assessed vulnerability.

Many communities will have a set of existing policies, plans, programs, resources, or institutions that are being deployed or can be deployed with little effort to adapt to climate change and reduce potential impacts. For example, a community that identifies reduced water supply due to rainfall and snowpack changes may already be developing new water sources or setting aside money to do so. This community has a high adaptive capacity in the case of water supply, since a solution to the climate change impact is readily implemented.

These existing resources should be identified to inform additional policy and program development. In addition to identifying measures that already directly address a climate impact, the policy audit can also provide insight into the type of policy action most successful in a given community. The following list includes local (city or county) policy that should be included in an audit (adapted from Boswell, Greve, and Seale, 2012):

**Plans**

General Plan
Area and Specific Plans
Local Hazard Mitigation Plan
Transit Plan
Urban Water Management Plan
Parks, Trails, and Open Space Master Plan
Downtown Plan

**Standards, Ordinances, Programs, And Policies**

Stormwater Management Program
Zoning Code
Building Code
Fire Code
Tree Ordinance
Floodplain Ordinance

The following tasks are recommended:

1. Conduct an audit of existing policies, operations, and assets/resources to identify actions in progress, planned, or readily implementable that will mitigate the identified impacts.
   a. For each impact described in Step 3, list the existing plans and policies that address the impact.
   b. For each policy, identify whether or not it has been implemented. Policy items in plans, which are necessarily general, may not yet be implemented. If the policy has been implemented, indicate whether it is an ongoing effort or complete. If it has not been implemented, indicate how much time and resources would be required to do so.
   c. Note the degree to which the existing strategy could be strengthened.
2. Combine the description of the impact (Step 3) and the current capability to address the impact (Step 4), determine a final rating of severity (low, medium, or high). This rating should reflect the collective climate adaptation team's view of the importance of an impact relative to local capacity to address it. These ratings will be used in subsequent steps.

## 4.5 Step 5: Evaluating Risk and Onset

Once the potential impacts have been identified, they should be adjusted based on level of uncertainty, the likely timeframe of impact onset, and capacity of the jurisdiction to respond (Steps 3 and 4). These adjustments will be critical in helping a community identify the highest priority impacts for climate adaption policy and programs. Although this is listed as a fifth step, it would likely be conducted in tandem with the

previous two steps of identifying impacts and local capacity. This step asks the climate adaptation team to rank impacts based on the level of certainty, the timeframe in which the impact is projected to occur, and the risk posed by the impact (a combination of impact and adaptive capacity).

### 4.5.1 Risk/Uncertainty

Risk is the likelihood or probability that a certain magnitude/extent/scale of potential impact will occur; this includes consideration of the timeframe of these likelihoods (near-term, mid-term, long-term). Lower risk or higher uncertainty may reduce the assessed vulnerability.
This is an assessment that combines the estimated certainty of the science projecting the climate impact and the certainty of the sector sensitivity. In general, impacts with higher probability should be ranked at a higher priority for community action.

The following tasks are recommended:

1. For each impact, assign a low, medium, or high uncertainty, based on the certainty of the primary or secondary exposure estimated in Step 1 (Table 1).
2. Adjust the certainty category based on the certainty of the impact sensitivity.

### 4.5.2 Timeframes

In general, impacts with a quicker onset should be ranked at a higher priority for community action. As in other assessment steps, timeframe cannot be precisely estimated. However, it is possible to categorize impacts as near-, mid-, and long-term. These timelines can be obtained from the Cal-Adapt tool (www.cal-adapt.org).

The following task is recommended:

1. For each impact, designate the timeline for expected impacts:
    a. Current—impacts that currently are occurring
    b. Near-term: 2020-40
    c. Mid-term: 2040-70
    d. Long-term: 2070-2100

### 4.5.3 Capacity to Respond

In some communities, the identified potential impacts may already be occurring whether they are related to climate change or not. For example, a community that is forecasted to have greater wildfire frequency may already suffer from significant wildfires; moreover, this community may already be implementing wildfire mitigation policies and programs. These communities should look to the climate change vulnerability assessment to evaluate how the existing hazard may change or to inform a change in priorities.

The following task is recommended:

1. Evaluate existing policy and program documents to identify current hazards related to climate. These may include the Safety Element of the General Plan, the local hazard mitigation plan, water supply studies, and other documents that may describe community sectors currently vulnerable due to existing climatic conditions.

# 5.0 Policy Development – Adaptation Policy Development Steps 6-9

5.0 Policy Development – Adaptation Policy Development Steps 6-9
5.1 Step 6: Setting Priorities for Adaptation Needs
5.2 Step 7: Identifying Adaptation Strategies
5.3 Step 8: Evaluating and Setting Priorities for Strategies
5.4 Step 9: Establishing Phasing and Implementation

The policy development phase translates the identified vulnerability and risk into implementable policy actions. The uncertainty of the projected changes and impacts, potentially high policy implementation costs, and the wide range of competing interests in any community make this process difficult. One way to navigate what can be a complex, time-consuming process is through the use of decision matrices (Step 6 and Step 8). A decision matrix can aid a community in balancing adaptation needs against uncertainty, other community goals, and time and funding concerns.

Setting priorities for adaptation needs and strategies must be based on the local social, political, economic, and environmental context. The same adaptation need may be critically important in one community and viewed as moderately important in another. These distinctions must be made collectively by community staff, key stakeholders, and concerned residents. The climate adaptation team should lead this process.

This section outlines a process for policy development that involves Steps 6 through 9 discussed in Section 2.0 (see Figure 3):

6. Setting Priorities for Adaptation Needs
7. Identifying Adaptation Strategies
8. Evaluating and Setting Priorities for Strategies
9. Establishing Phasing and Implementation

## 5.1 Step 6: Setting Priorities for Adaptation Needs

The first step in policy development is to identify the climate-related impacts that require policy development. Not all identified impacts require immediate action. High levels of uncertainty, impact onset being in the distant future, or effective existing policy can all be reasons to delay policy development for a particular impact. Similarly, there will be a set of impacts that require action immediately due to the potential severity of impact, low cost, or the time that effective policy implementation may take. Setting priorities for adaptation needs also results in communities being more able to dedicate the necessary staff and funds, because the efforts may not need to occur all at once.

The following tasks are recommended:

1. Collect the categorical ratings for impacts (Step 3) and risk (Step 5), and use a risk matrix to identify those impacts that warrant strategy development. This approach allows room for strategy development to address impacts with the potential to be so disruptive that they deserve action even if unlikely. The climate adaptation team should determine the shading in the matrix. wIt could be decided that additional areas of the matrix warrant policy development.

Figure 5 shows a sample matrix that can be adjusted depending on community characteristics. The sample matrix combines impact potential and adaptive capacity with scientific certainty and community sensitivity to a given impact.

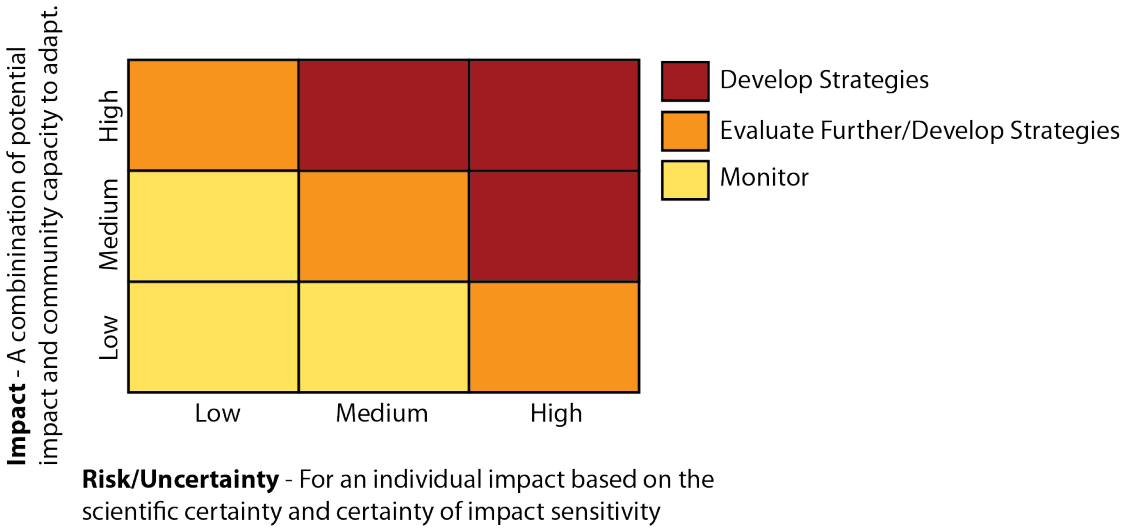



Figure 4. Example Of An Adaptation Needs Decision Matrix.
[Adapted from City of New York, 2009]

2. Using the decision matrix, develop a list of adaptation impacts that have been identified for immediate strategy development. In a sense, a jurisdiction should be able to organize all of its identified impacts (adaptation needs) into one of the cells on the matrix. The rating for each impact will vary by jurisdiction based on their location and community characteristics.

## 5.2 Step 7: Identifying Adaptation Strategies

One of the greatest challenges in developing adaptation strategies is the fact that policies are being developed to address impacts that can be difficult to accurately predict and that may occur many years in the future. These strategies must be as varied as the biophysical settings and community types in the state. In addition, community and political support for these strategies may require that they address community needs above and beyond climate adaptation.

The Adaptation Strategies in Part 3 lists many potential adaptation strategies and some of the necessary considerations for tailoring them for local use. The collection of strategies included in Part 3 is not exhaustive. Jurisdictions should think creatively about the best manner in which to address a community's adaptive needs.

Characteristics of good adaptation policy include the following (Smit et al., 2000; de Loe, Kreutzwiser, and Moraru, 2001; Smit and Wandel, 2006; Boswell, Seale, and Greve, 2012):

- **Flexible.** Adaptation planning occurs in a setting that is continually changing. Climate science is uncertain and evolving with new reports and updates being released regularly. Local conditions also evolve over time. As a result, adaptive policy should be robust, meaning it will be applicable even if conditions change. Strategies should be adjustable over time as conditions and projects change.
- **Cost-Effective.** Communities have a wide range of needs above and beyond climate adaptation. Setting priorities for adaptation policy development is made even more difficult by the fact that successful implementation (benefits) may be in the distant future. As a result, the best adaptation strategies meet multiple community needs and provide both short- and long-term benefits.
- **Specific.** Adaptation needs often have specific characteristics by addressing, for example, a particular region of impact, speed of onset, or scale of consequences. The most effective strategies are tailored for these characteristics.
- **Integrative.** The most important impacts for a community are often secondary impacts such as wildfire, crop yield, or human health. These impacts commonly result from the interaction of multiple aspects of climate change (e.g., the interaction of temperature and precipitation). Local and regional entities often do not have the jurisdictional control to affect climate change directly. For example, no individual city is going to stop the average global temperature from rising or the ocean from acidifying. As a result, climate adaptation strategies should focus on secondary impacts by preparing an affected sector to be more resilient. For example, many climate impacts have the potential to harm the local economic base. Adaptation policy, in this case, may be an economic diversification effort that will lessen the impact of climate-related economic outcomes.

The outcome from this step should be a strategy or suite of strategies for each of the impacts identified in Step 6 as warranting policy development.

## 5.3 Step 8: Evaluating and Prioritizing Strategies

This step is based on characteristics of the impact being evaluated and those of the policy devised to address it. As in the setting of priorities for adaptation needs (Step 6), this step also relies on a decision matrix. The use of the matrix not only aids in making decisions in the context of complexity, but also makes the strategy development process transparent and more easily communicated to community staff and residents.

The relevant information about each climate impact has already been identified through earlier steps in the process. The information needed for each strategy includes projected costs of implementation, community co-benefits, duration of implementation, and social acceptance. The information regarding each strategy should be developed by the climate adaptation team. This step is likely most efficiently addressed if completed simultaneously with Step 7.

The following tasks are recommended:

1. Evaluate each strategy. Information helpful for systematic assessment includes the following (Smit et al., 2000; Smith, Vogel, and Cromwell, 2009; Boswell, Seale, and Greve, 2012):
   a. Costs. This should include the initial costs, as well as any ongoing personnel or funding requirements. If possible, potential sources for the funding should also be identified.
   b. Community Co-Benefits. The other benefits that a community may experience if the strategy is implemented should be identified. These can include greenhouse gas reduction, economic improvement, and many other potential community goals. These co-benefits, particularly those experienced in the near term, are often are helpful in garnering community and political support for a strategy.
   c. Duration of Implementation. There are two parts to this consideration of timing: (1) the period of time necessary to initiate implementation, and (2) the length of the implementation period. Some strategies may rely on technological advancements or require policy change prior to implementation. This will delay the initiation of a strategy. Similarly, implementation duration can vary widely. An update of the building code to reduce fire vulnerability will take much less time than the eventual relocation of a coastal water reclamation facility.
   d. Social Acceptance. This refers to the fact that many adaptation policies will be housed in plans that require community feedback, advisory board approval, and adoption by elected officials. To successfully navigate this process, a strategy's likely level of approval should be assessed. This does not mean that less popular strategies should be abandoned but that, if these strategies are pursued, additional time or outreach efforts should be developed to accompany the strategies.

2. Using the sample matrix in Figure 5, evaluate the ease of implementation (e.g., cost and time) in relationship to the impact onset. This can set up as a series of individual matrices or organized into a table that displays all of the potential considerations (see Table 3). The Figure 5 matrix combines impact potential and factors that influence strategy feasibility. As with the matrix in Step 6, the specifics should be determined by the climate adaptation team. In particular, the climate adaptation team should determine the definition of near-, mid-, and long-term, from a policy development perspective.

3. Organize the strategies according to when they need to be implemented (near-, mid-, and long-term.

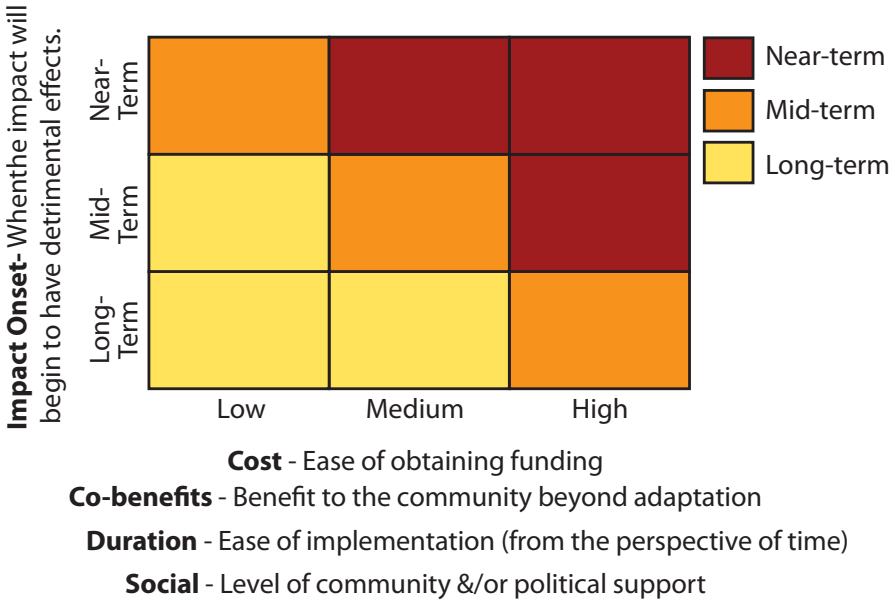



Figure 5. Example adaptation strategy prioritization matrix.
[adapted from City of New York, 2009]

Table 3. Example of a Table Comparing Decision Matrix Outcomes and Defining the Implementation Phase (Near-, Mid-, or Long-Term)

| | Impact Addressed | Impact Onset | Implementation Cost | Funding Availability | Co-benefits | Preparation Time | Implementation Time | Community Support | Implementation Phase |
|---|---|---|---|---|---|---|---|---|---|
| Strategy 1 | SLR | Mid- | High | Med | High | Low | Med | Med | |
| Strategy 2 | … | … | … | … | … | … | | | |
| … | | | | | | | | | |

## 5.4 Step 9: Establishing Phasing and Implementation

As with other types of planning strategies, success in phasing and implementation of climate adaptation strategies depends on a number of factors. A responsible or lead department, staff member, or entity should be defined as responsible for implementation; a phasing program should be established; a funding source should be identified and obtained; and a monitoring program should be developed.

In addition to these factors, long-term effectiveness relies on strong political leadership. Adaptation policies often address impacts projected to occur in the future and are unlikely to yield observable benefits in the short term. Successful implementation therefore relies on consistent and sustained support. Strong leadership is needed due to the diverse nature of adaptation policy and the necessity for continual updating. In the long term, actions by many departments must continue to be coordinated.

The following tasks are recommended:

1. Identify the responsible party. Defining a specific individual, department, agency, or organization as responsible for implementation is one component of assuring that a strategy is implemented rather than simply included in plan or guidance document. The climate adaptation team can define the responsible parties and can also provide a forum for implementation progress to shared.

2. Identify funding. Perhaps the most difficult and important component to assuring implementation is identifying a funding source to support identified strategies. Each strategy should have an associated estimated cost that includes material cost of the strategy, staff time, administrative support, associated outreach, and long-term monitoring. Adaptation strategies must compete with all of the other needs in the community. This is why identifying strategies that can meet multiple community needs is suggested. There are a variety of ways in which adaptation strategies can be funded including government grants, general funds, taxes and fees (including impact fees), bonds, and more.

3. Establish systems for monitoring and diffusion of information and technology. Adaptation occurs in a dynamic setting. As a result, even while individual strategies require monitoring to assess effectiveness, the science that projected the impact being addressed is changing as well. A comprehensive adaptation program must track scientific updates as well as the tools and technology available to address the impact projections. The State of California has established web resources that make available the findings from ongoing research on climate change and the tools available to address it. Communities should make an effort to stay informed of these advances.

4. Establish feedback loops. The monitoring of strategy effectiveness and science advancements is only valuable if it is used to adjust adaptation strategies when necessary. An adaptation strategy should have periodic review and update integrated into its implementation plan. Given the uncertainty inherent in climate projections and impact assessment, an adaptive approach is critical to long-term policy effectiveness and efficient use of resources.

# 6.0 Vulnerability by Sector

The vulnerability that a community experiences as a result of climate change is a product of biophysical setting in combination with the characteristics of the community, ranging from its built pattern to social, political, and economic characteristics. As a result, a locally appropriate vulnerability assessment cannot be developed at a state, or even regional, scale.

This section seeks not to develop a vulnerability assessment, but rather to highlight some of the considerations that should be part of the process when a community conducts a vulnerability assessment. The discussion addresses considerations by "sector," or climate impact area.

The description of the each sector begins by summarizing the manner in which climate change may affect the sector. In most cases, detailed state guidance has been developed that can provide greater depth than what is presented in the APG. Communities seeking additional information should refer to these documents. Where available, a list of additional resources is provided for each sector. Following the climate impact summary, the considerations critical to vulnerability assessment are presented. The information required to address these considerations should be developed through representatives on the community climate adaptation team.

This section covers vulnerability assessment, the first five steps in adaptation policy development. The policy development steps require a jurisdiction to evaluate adaptation needs and potential impacts based on local considerations. These more specific considerations are discussed at a smaller spatial scale in Part 2, Regions, of the APG.

The impacts associated with each sector overlap. For example, flooding may affect infrastructure. Thus, the evaluation of this disruption could be housed in either the sector focused on flooding or that evaluating infrastructure. Where overlap occurs, the other location where a particular impact is discussed is identified.

The intent of the APG is not to comprehensively cover impacts in each sector. Many state agencies have or are developing much more comprehensive evaluations of climate change with respect to impacts on particular sectors or agency missions. The APG identifies in-depth guidance where it is available. The APG is not intended to replace a local vulnerability assessment. The aim of this section is to highlight some of the issues that may emerge during a vulnerability assessment and identify possible sources and methods for addressing them.

## 6.1 Equity, Health, and Socio-Economic Impacts

This sector reviews the public health and socio-economic impacts of climate change, focusing on individuals and groups most vulnerable to these impacts. The information for this sector was gathered primarily from the following four areas of concern in the climate change literature: equity (social equity/environmental justice), social vulnerability, public health, and economic impacts. The first three areas provide data regarding, and assessments of, vulnerable human populations; thus, these areas are particularly useful for understanding and making vulnerability assessments on the local level. The economic literature reviews the effects of climate change on specific industries (e.g., agriculture or tourism) and overall economic growth. All four areas, and their relationship to vulnerability assessments, are briefly discussed below.

Equity discussions bring together analyses of a wide range of climate change impacts—social, economic, health, environmental—to highlight individuals and groups who are most vulnerable. Equity concerns are based on an assertion that climate change impacts do "not affect everyone equally" (Morello-Frosch et al., 2009, pg. 1) and highlight the disproportionate effects of climate change on people of color, the poor (Pastor, 2010), and other vulnerable and socially marginalized populations. (Shonkoff et al., 2011; OEHHA, 2010b). This literature also concerns itself with the potentially inequitable consequences of climate adaptation strategies and encourages agencies to consider and monitor the impacts of their own policies. (Morello-Frosch et al., 2009; Pastor, 2010; Shonkoff et al., 2011; Pacific Institute, 2010) Data provided in both the social vulnerability (Cutter et al., 2009) and public health literature (CDPH, 2012) support concerns regarding the inequitable impacts of climate change

Social vulnerability is defined as "the intersection of the exposure, sensitivity and adaptive capacity of a person or group of people" to climate change (Pacific Institute, 2010, pg. 1). In the social vulnerability literature, data are used to assess the people most at risk to climate change due to a combination of their social and demographic characteristics (e.g., economic status, age, and ethnicity), level of exposure to impacts likely to occur, sensitivity to impacts (e.g., health condition, occupation), and adaptive capacity (e.g., networks, knowledge, attitudes) (Wongbusarakum and Loper, 2011; Cutter et al., 2009) Thus, social vulnerability analyses are, by definition, vulnerability assessments, and the concepts and data found in this literature are essential for making local vulnerability assessments. Because social vulnerability analyses frequently focus on exposure, sensitivity, and adaptive capacity, this sector uses these steps for discussing vulnerability (eliminating Step 3, Potential Impacts).

Public health literature reviews health impacts resulting from the direct effects of climate change (e.g., rising temperature, increasing climate variability, increased rainfall, and drought), as well as its indirect effects (e.g., sewage overflows resulting from flooding, contaminated groundwater from salt water intrusion, and vector-borne diseases from changes in precipitation) (Maibach et al., 2011In addition to covering health impacts affecting entire communities, the literature covers particularly vulnerable populations (CDPH, 2012), reinforcing the concerns for these populations found in the social vulnerability literature. "Climate change is expected to have significant and far-reaching public health consequences" (CDPH, 2012, pg. 5). While not creating any "new health problems" (Samet, 2010, pg. 1), the injury, chronic and infectious diseases, and death associated with the direct and indirect effects of climate change are predicted to increase in scale and intensity (CDPH, 2012). Because public health agencies currently address related health impacts, they can provide community planners and emergency responders with resources (such as databases of vulnerable populations), guidance (such as health-related policies for inclusion in climate action plans and general plans), and literature on the co-benefits of climate action planning on public health and health-related policies (CDPH, 2012).

Recent literature on the economic impacts of climate change covers potential effects upon California's economic growth (Sanstad et al., 2011; CEC, 2009) and on specific industries within the state, such as agriculture (Medillin-Azuara et al., 2011; Deschenes and Kolstad, 2011) and tourism (Pendleton et al., 2011). While this literature does not always directly address impacts on individuals or groups, it provides a context for assessing local populations that may be vulnerable because they rely on industries affected by climate change. Taken together with the equity and social vulnerability material, the economic literature can be used to assess the populations most vulnerable to the economic impacts of climate change.

### 6.1.1 Exposure

In this section, broad public health and socio-economic impacts are grouped under the following associated climate changes and impacts: temperature and precipitation, air quality, wildfires, and sea level rise. The impacts reviewed are taken from a number of sources (CDPH, 2012; Shonkoff et al., 2011; OEHHA, 2010; Pacific Institute, 2010; CNRA, 2009; Maibach et al., 2011; CDPH, 2008; English et al., 2007; Basu and English, 2008; Dreschler et al., 2006).

#### Temperature and Precipitation

**Public Health Impacts.** Short-term extreme temperature changes such as heat events and long-term increases in average temperature are expected to impact public health (OEHHA, 2010; Pacific Institute, 2010; Cayan et al., 2008; Gershunov and Cayan, 2008). The rising average surface temperatures brought on by climate change predict a substantial increase in the number, duration, and severity of heat waves (CDPH, 2012). Impacts associated with heat events include premature death, cardiovascular stress and failure, and heat-related illnesses such as heat stroke, heat exhaustion, and kidney stones.

Urban dwellers are more at risk because they reside on "heat islands" (geographic zones that are warmer than surrounding suburban and rural areas because of pavement, buildings, other infrastructure, and lack of vegetation) (CDPH, 2008; English et al., 2007). This results in higher urban temperatures due to several factors, including the loss of natural cooling from shade trees and waste heat from vehicles, factories, and air conditioners (Basu and English, 2008). The highest percentages of impervious surfaces are in the urban areas of Los Angeles and San Diego counties (English et al., 2007). Southern California's urban centers are warming more rapidly than other parts of the state (English et al., 2007).

Inland low-lying areas of California are predicted to have more extreme heat events. During the 2006 heat wave in California, the majority of the 140 deaths immediately associated with the heat wave occurred in inland low-lying areas of California such as the Central Valley and Imperial and Riverside counties (Drechshler et al., 2006).

Impacts associated with increased average temperature include cardiovascular disease; an increased number and range of vector-, water- and food-borne diseases; asthma; allergies; harmful algal blooms causing skin disease and poisoning; and vulnerability to wildfires and air pollution (CDPH, 2008).

Intense rainstorms may produce flooding resulting in injuries and death from drowning. Potential contamination of potable water, wastewater, and irrigation systems may negatively affect the quality of water supply, resulting in an increase of water- and food-borne diseases (Confalonieri et al. 2007; USGCRP, 2009).

A reduction in precipitation in combination with an increase in average temperatures may worsen incidence of drought, which in turn can result in hunger and malnutrition caused by disruption in food and water supplies (Cutter et al., 2009; Shonkoff et al., 2011).

**Socio-Economic Impacts.** Extreme heat events and intense rainstorms could require evacuation and temporary displacement of people. Reduced precipitation in combination with increased temperatures can produce drought, diminished snowpack, changes to the agriculture and forestry sectors (including changing patterns and yields of crops, pests, and weed species), and disruptions in the food and water supply. These impacts may, in turn, have a number of deleterious social and economic impacts on human populations, including increased cost and conflict over food and water, and unemployment and displaced jobs (e.g., in the agriculture, forestry, and tourism industries) (Shonkoff et al., 2011; Pacific Institute, 2010; CDPH, 2008).

## Air Quality

**Public Health Impacts.** Many Californians living in or near urban areas currently experience the worst air quality in the nation (Messner et al., 2009). Changes in temperature are expected to exacerbate already impaired air quality, and particularly ozone levels and particulate matter in certain regions, leading to an increased incidence of asthma, allergies, chronic obstructive pulmonary disease (COPD), and other cardiovascular and respiratory diseases and an increased risk of skin cancer and cataracts (Samet, 2010; Confalonieri et al., 2007; Kahrl and Roland-Holst, 2008; Pacific Institute, 2010).

Foothills and mountainous communities may be particularly subject to respiratory problems and heat stress due to a combination of higher ozone levels, higher elevations, and increasing temperatures in these areas (English et al., 2007; Drechsler et al., 2006). In areas such as these, conditions conducive to ozone formation are projected to increase by as much as 25 to 80 percent by 2100 (Drechsler et al., 2006). Creation of ground-level ozone is driven by photochemical reactions, and warmer temperatures result in increased production." (Pacific Institute, 2010, pg. 5))

**Socio-Economic Impacts.** Socio-economic factors, such as ethnicity, gender, and income level, contribute to the risk of adverse health impacts from air pollution (Pacific Institute, 2010). This is discussed further under sensitivity.

## Wildfires

**Public Health Impacts.** The increased severity and frequency of wildfires and length of the fire season may result in additional Injuries and death from burns and smoke inhalation; eye and respiratory illnesses and exacerbation of asthma, allergies, chronic obstructive pulmonary disease (COPD) and other cardiovascular diseases from air pollution; and direct risks to firefighters and other emergency response personnel (Lipsett et al., 2008; Pacific Institute, 2010).

**Socio-Economic Impacts.** Increased incidents of wildfires can lead to evacuation, temporary displacement, and property damage. Risk of erosion and land slippage subsequent to fires can lead to temporary or permanent displacement and property damage or loss (CDPH, 2008; Pacific Institute, 2010).

### Sea Level Rise

**Public Health Impacts.** Sea level rise will adversely affect public health for those living in coastal and delta areas and along coastal rivers. The kinds of impacts anticipated include flooding of septic systems near coastlines that can pollute the ocean; compromise of nuclear power plants, leading to contamination; extreme high tide and storm surges, causing injuries and drowning; and extension of the fresh water/salt water transition zone farther inland, causing contamination of water supply (NRC, 2010).

**Socio-Economic Impacts.** Extreme high tide and storm surges associated with sea level rise could result in evacuation, temporary and/or permanent displacement, and property damage or loss. Compromised nuclear power plants might result in evacuation and temporary or permanent displacement, loss of electric power, and property damage or loss. Coastal erosion can harm recreational activities, tourism, and the tourism industry, resulting in unemployment and displacement. Changes in ocean conditions, including an increase in marine biotoxins, that substantially alter the distribution and abundance of major fish stocks and shellfish may damage the fishing industry and lead to increased seafood prices or shortages, changes in tourism in coastal communities, and unemployment and displacement of those who work in the fishing and tourism industries. Extension of the fresh water/salt water transition zone farther inland may affect aquifers and require treatment or abandonment of fresh water wells (CDPH, 2008; Pacific Institute, 2010).

## 6.1.2 Sensitivity

This section describes groups/conditions with increased sensitivity to climate change and factors that affect the ability to address—prepare for, prevent, respond, and recover from—impacts. The information regarding these factors was gathered from a number of sources (CDPH, 2012; Schonkoff et al., 2011; Pacific Institute, 2010; OEHHA, 2010a; CNRA, 2009; CDPH, 2008; Cox et al., 2006).

There is considerable overlap between the groups and conditions. This overlap ultimately can help identify the people at greatest risk of being adversely affected by climate change. The social vulnerability literature has explored and tested a variety of assessment methods (e.g., vulnerability assessment indices) for determining populations who fit into a number of categories or are predicted to experience a number of impacts (Cutter et al., 2009; Sadd et al., 2011). Cal EPA/California Office of Environmental Health Hazard Assessment (OEHHA) and the California Department of Public Health have recently completed the following studies regarding assessment methods that are of use to local agencies:

- Cumulative Impacts: Building a Scientific Foundation (2010) (Cumulative Impact Assessment)
- ASTHO Climate Change Population Vulnerability Screening Tool (2012) (Environmental Justice Screening (ESJM) Assessment)

Groups/conditions with increased sensitivity include:

- Age—Children and the elderly
- Chronic disease or disability
- Race/ethnicity/gender
- Socio-economic status
- Occupation

Extrinsic factors that affect a population's ability to address impacts include:

- Material resources, such as health insurance or air conditioners, that can improve prevention of or recovery from impacts.
- Basic lifelines, such as access to public transit, cars or telephones, in the event of climate-induced disaster.
- Information/knowledge/familiarity with impacts affecting those who live in areas currently not experiencing extreme events and, thus, familiarity with information regarding prevention or response. For instance, extreme heat events are less likely along the coast than in inland valleys. When extreme heat events do occur, however, vulnerable populations may be severely affected because of a historic lack of adaptive capacity having to do with historically milder temperatures. Vulnerable populations include those who do not speak English and/or have recently moved to a region and thus do not have adequate knowledge of regional hazards and methods of evacuation.
- Level of social cohesion and civic engagement/participation, affecting those who may have been marginalized or disenfranchised from the political process because of ethnicity or immigration status.
- Built environment, such as living in homes with fewer rooms, on higher floors of multi-story buildings, in poor-quality structures, near urban heat-islands, and/or without air conditioning.

## Age

Elderly persons ( > 65 year olds) are especially susceptible to the adverse effects of climate change because of their "reduced ability to acclimatize to changing temperatures and higher likelihood of pre-existing chronic health conditions" (Health Canada, 2006). In addition, many elderly people suffer from impaired cognitive function, which can cause them to underestimate extreme weather conditions and put their health at risk as a result, especially if they fail to seek the necessary medical attention or are unable to take recommended precautions. People over the age of 65 have the largest increase in mortality with increased concentrations of ozone (Medina-Ramon and Schwartz, 2008) Extrinsic factors that can affect the elderly are social isolation (Wang and Yasui, 2008) and dependence on others, including the elderly living in institutional settings (Moser and Ekstrom, 2010; Caruson and MacManus, 2008).

Infants and children (< 5 years old) are also extremely susceptible to adverse climate change. Because of their physiology and morphology, they are less able than adults to maintain an optimum core body temperature when exposed to environmental heat, especially when engaged in physical activity at ambient temperatures greater than 95 degrees. Children are particularly vulnerable to high levels of ozone and particulate matter (Medina-Ramon and Schwartz, 2008). Children also require more time to acclimatize than do adults, and they are less likely to sense thirst and voluntarily replenish fluids during extended physical activity, which can lead to dehydration (Medina-Ramon and Schwartz, 2008). Like the elderly, children are dependent on others within the family for their care, which means in times of emergency they may receive less attention and therefore need more recovery time (Shonkoff, 2011; CDPH, 2008).

## Chronic Disease or Disability

Extremes in temperature accelerated by climate change put greater stress on the already underlying health status of a population. In addition, higher pollen counts brought on by excessive rain have a disproportionate effect on asthmatics (Shonkoff et al., 2011; CDPH, 2008; Medina-Ramon and Schwartz, 2008). People with lung disease and/or asthma are particularly sensitive to ozone and particulate matter (Medina-Ramon and

Schwartz, 2008). Climate change may also accelerate the incidence and geographic distribution of infectious diseases and conditions that are vector-borne (i.e., spread by mosquitoes and ticks), to which individuals with chronic disease may be more susceptible. In California, three vector-borne diseases are of particular concern: West Nile virus, human hanta virus, and Lyme disease. The range, spread, and incidence of infectious diseases can be influenced by many different factors associated with climate change. Greater rainfall accompanied by higher temperatures also lengthens the window for disease transmission in many places where certain diseases are already likely to occur. Other vulnerable groups include people with disabilities and families with disabled members (Pacific Institute, 2010). Extrinsic factors that affect some of these groups include their dependence on others for assistance during evacuation (Moser and Ekstrom, 2010; Caruson and MacManus, 2008).

### Race/Ethnicity/Gender

Communities of color, which tend to be concentrated in urban areas, are especially vulnerable to the adverse effects of climate change for a number of reasons. Analysis of census data has shown that people of color, regardless of income, tend to live closer to the heaviest-polluting industries and experience more exposure to the effects of air pollution and urban heat islands due to the concentration of these populations in more disadvantaged urban areas. Ethnicity may carry with it extrinsic factors, such as linguistic isolation (affecting access to information) and immigration status (affecting access to political representation) that increase vulnerability (Cox et al., 2006; Shonkoff et al., 2009). Communities of color, women, and members of the lesbian, gay, bisexual, and transgender (LGBT) community may have been misrepresented or disenfranchised from the political process, which may affect exposure, sensitivity, and adaptive capacity to hazards. These groups may experience a "cumulative burden" of harmful exposures, and climate impacts should be considered with this in mind (Shonkoff et al., 2011; Pacific Institute, 2010; Shonkoff et al., 2006; Morello-Frosch et al., 2009; Cutter et al., 2009; Cox et al., 2006).

### Socio-Economic Status

Low-income individuals are especially vulnerable to climate change for a number of reasons, primarily extrinsic factors such as a lack of resources. Many low-income individuals living in cities will be exposed to greater pollution because of existing exposures, air pollution, and heat-island effects. Low-income communities are often under-insured and therefore slower to recover from natural disasters caused by climate change (Shonkoff et al., 2011; OEHHA, 2010a; Fothergill and Peek, 2004; Bolin and Bolton, 1986). They may not have the resources to evacuate a disaster, i.e., they lack a car and/or access to public transit; during emergency response, they are less likely to have their needs met (Cutter and Finch, 2008; Fothergill and Peek, 2004). Low-income urban communities are particularly vulnerable because of heat island effects and because they may unable to afford the resources (such as air conditioning) to stave off impacts (Schonkoff, 2011; OEHHA, 2010b). Increases in prices for food and water will strike low-income families the hardest because they already spend a larger portion of their incomes on these necessities than higher-income families (Shonkoff, 2011; Pacific Institute, 2010). Because of a lack of shelter, the homeless are at greater risk of suffering the adverse effects of exposure to temperature and rainfall (Pacific Institute, 2010).

### Occupation

Certain vocations are more prone than others to the effects of climate change. Agricultural and other outdoor workers are adversely affected by extended periods of high heat (Medina-Ramon and Schwartz, 2008). People who work or spend a lot of time outdoors, such as employees of the tourism industry and agricultural workers, are particularly vulnerable to high levels of ozone and particulate matter (Medina-Ramon and Schwartz,

2008). Migrant farm workers are at risk from climate change because they lack permanent shelter. Occupation and immigration status are extrinsic factors that contribute to vulnerability, as occupation may require long workdays and strenuous activities and status may affect the capacity to protect rights or engage in the political process (Shonkoff et al., 2009).

People who exercise outdoors can put themselves at risk by working too strenuously at elevated temperatures. Jobs in the tourism industry, which often congregate in coastal areas and mountainous regions, especially suffer when there are climactic extremes. High seas that erode beaches and too much or too little snowfall at ski resorts exemplify climate burdens placed on areas that rely on tourism for their economic well-being (Shonkoff et al., 2011; CDPH, 2008; Basu and English, 2008).

## Factors Indicating Sensitivity

The following table lists some of the factors indicating sensitivity. This type of information is used in the previously mentioned "social vulnerability," "cumulative impacts," and "environmental justice screening method" assessments.

Table 1. Facts that Contribute to Climate Change Sensitivity

| Characteristic | Variables |
|---|---|
| Age | % over 65/% Elderly living alone/% under 5 |
| Chronic disease/disability | % with self-care disability/work-related disability/mobility disability<br>% nursing home residents<br>% group home residents<br>% population in hospitals<br>% population in special care facilities |
| Race, ethnicity, and gender | % Asian<br>% African American<br>% Hispanic/Latino<br>% Non-Hispanic/Latino<br>% Native American<br>% other<br>% females below poverty level<br>% female-headed households |
| Socio-economic status | % in poverty: individuals/households<br>Income levels: individuals/households |
| Occupation | % agriculture/% forestry/% tourism |
| Lifeline | % housing with no telephone |
| | % that use public transportation/ average vehicles per household |
| Information/knowledge/ familiarity | % second language spoken in household/% English proficiency levels<br>% new to region/% new to U.S./% migrant workers<br>% individuals who are homeless /% individuals who are transient |
| Citizenship status | % foreign born/% non-citizen |
| Built environment | Housing density (in square miles)/housing built prior to 1939<br>% living in mobile homes/% households with structural deficiencies/households with water supply problems |

(CDPH, 2012; Shonkoff, et al., 2011; OEHHA, 2010b; Cutter et al., 2009; Cox et al., 2006)

### 6.1.3 Adaptive Capacity

This section reviews questions to help jurisdictions determine their adaptive capacity for addressing the predicted impacts on vulnerable populations discussed in the previous sections. Jurisdictions should review their policies and programs in coordination with agencies and organizations—local public health departments, emergency preparedness and first responders, non-profits, community development corporations, philanthropic organizations, local religious groups, ethnic community groups, and others—that serve and represent vulnerable populations and/or influence the previously listed factors influencing adaptive capacity.

#### General Questions

- Have agencies and organizations been contacted that can identify and reach vulnerable populations and provide them with information on what they need to know about the risks of climate change and what can be done to address them? Has a local network/committee of these agencies and organizations been created to work on climate change issues and impacts? Many of these agencies and organizations, particularly public health agencies and emergency responders, are already addressing the health and other impacts experienced by vulnerable groups. It is vital that jurisdictions familiarize themselves and build upon existing work in the most efficient manner possible.
- Does the local health department or department responsible for emergency preparedness have community-wide assessments of the location of the most vulnerable populations, such as the elderly, persons with disabilities/special needs, immigrants and non-English-speaking residents, and others who might lack material resources and or have physical limitations?
- Do transportation policies and programs and emergency preparedness plans consider social equity issues associated with access to transportation?
- What type of public education and community outreach efforts are underway and are they accessible to diverse groups and through diversity of agencies and media? Are special efforts made to address the participation of disadvantaged communities?
- Do members of these vulnerable communities sit on the jurisdiction's boards and commissions? Are there educational programs available to familiarize these communities with governmental functions and to empower them to participate in their own governance?
- Have the locations of polluting facilities, natural hazards, and heat islands been mapped along with the vulnerable populations adjacent to these facilities?
- Are local employers and business associations participating in local efforts to address climate change and health and socio-economic impacts upon employees?
- If your jurisdiction is unaccustomed to extreme heat events or participation, have you begun to educate your community about a change in preparedness?
- Do the jurisdiction's general plan, transportation plans, area plans and CEQA analyses include approaches to land use and transportation that promote health, such as the promotion of walking and biking through increased urban residential density and land use mix (e.g., Sustainable Community Plans, Climate Action Plans); road connectivity and bike/ walk infrastructure; enhanced streetscape design; "safe routes to school," "green tools for schools," and increased public transit; increased open space and parks; and improved access to healthy foods through school and community gardens and local farmers' markets?
- Does the jurisdiction's general plan include a health element? Does its CEQA process require a health impact analysis?

### Questions Regarding Extreme Heat Events (Heat Waves)

- Are early warning systems in place?
- Are cooling centers readily accessible and located in familiar places, both in terms of locale and transportation options, for vulnerable populations?
- Are there vulnerable members of the community who are without air conditioning? Are there programs available to provide air conditioning units?
- Do plans require or promote additional open space, green space, shade cover, urban forests, community gardens, parks, and trees and other vegetation that address the impacts of heat islands and heat events upon agricultural and tourism workers?
- Has the community considered adoption of community-level cooling strategies such as white or green roofs, cool pavements, cool parking lots, and land use and building design that can result in cooling?

### Questions Regarding Air Quality

- In coordination with the air quality management district, have the locations of polluting facilities been mapped along with the populations adjacent to these facilities?
- Have local planning efforts related to attaining better air quality been linked to addressing climate change impacts and social equity issues?

### Questions Regarding Flooding and Wildfires

- Do policies and regulations address the reduction of impervious surfaces and require the use of permeable surfaces (in parking lots and roads, for instance)?
- Do local regulations address prevention through minimum brush clearance requirements, use of fire-resistant landscaping and non-combustible materials for roofs and exteriors, clearing of areas around propane tanks, and proper storage of flammable materials?
- Has the capacity of local water and sewage treatment facilities been modernized or expanded to meet predicted worst-case precipitation scenarios?
- If your jurisdiction includes coastal communities, have you begun to educate communities, and particularly socially vulnerable populations, most likely to be displaced as a result of sea level rise? Do land use plans address the need to change permitted uses and structures in these areas?

## 6.1.4 Onset and Risk

In the Public Health Climate Change Adaptation Strategy for California (2008), the California Department of Public Health identifies numerous health impacts resulting from anticipated increases in temperature, changes in precipitation, and sea level rise, including heat stress and heat-related illness, heat stroke, skin cancer, allergies, asthma, flooding, drowning, and increases in water-borne and vector-borne illnesses. Concerns about these impacts, along with many others, can be found throughout the academic literature on climate change and public health. Unfortunately, the relationship between climate change and the magnitude of many of these impacts is still uncertain (Basu and English, 2008), making an assessment of onset and risk difficult.

While the magnitude of risk associated with immediate and long-term impacts is still somewhat uncertain, the

literature does appear to agree that among the most significant public health impacts are those resulting from extreme heat events, air pollution (primarily from ozone and particulate matter), and precipitation changes that produce flooding and wildfire. These short-term events can result in significant damage to property, displacement, injuries, and death. Social vulnerability analyses have documented the sensitivity and adaptive capacity of a number of populations to these impacts, and because these events have potentially catastrophic effects (e.g., Hurricane Katrina), many jurisdictions may judge them to hold the greatest risk and require immediate attention. If a positive note can be heard in all of this, it is that these impacts are not new, and as such, public health officials and emergency responders have been addressing them and have tools to identify and reach out to vulnerable populations. A partnership among agencies and organizations concerned with public health and social equity will be the most efficient and effective way to address these concerns.

Additional Resources

- A Review of the Social and Economic Factors that Increase Vulnerability to Climate Change Impacts in California (2010)
- Indicators of Climate Change in California: Environmental Justice Impacts (2010)
- The California Office of Environmental Health Hazards Assessment website: http://oehha.ca.gov/ej/index.html
- The California Environmental Protection Agency's Environmental Justice Program website: http://www.calepa.ca.gov/envjustice/
- The Climate Gap: Environmental Health and Equity Impacts from Climate Change Mitigation Policies in California (2011)
- ASTHO Climate Change Population Vulnerability Screening Tool (2012)
- Climate Action for Health: Integrating Public Health into Climate Action Planning (2012)
- California Adaptation Strategy, Chapter 4, Public Health (2009)
- Public Health Climate Change Adaptation Strategy for California (2008)
- The California Department of Health's website devoted to climate change: http://www.cdph.ca.gov/programs/CCDPHP/Pages/ClimateChange.aspx

## 6.2 Ocean and Coastal Resources

The Ocean and Coastal Resources Sector addresses natural resource issues within the coastal zone and coastal-dependent land uses and infrastructure that may be affected by climate change. The most prominent climate change factor is sea-level rise (SLR),which will exacerbate an existing problem with coastal erosion and flooding. The entire coastal zone of California is susceptible to the effects of SLR including bays and estuaries.

California has about 1,110 miles of coastline and has 1.5 million acres of land within the coastal zone. Major cities such as Los Angeles, San Diego, San Francisco, and Long Beach lie within the coastal zone and are highly dependent on the cultural, social, and economic benefits that access to the coast and oceans provide.
The Pacific Institute (2009) estimates that a 1.4 meter rise in seal level by 2100 would result in the following:

- Put 480,000 people at risk of a 100-year flood event, given today's population; this includes large numbers of people at risk with heightened vulnerability, including low-income households and communities of color.
- Put a wide range of critical infrastructure, such as roads, hospitals, schools, emergency facilities, wastewater treatment plants, power plants, seaports and airports, hazardous waste facilities/sites and at increased risk of inundation in a 100-year flood event.
- Put nearly $100 billion (in year 2000 dollars) worth of property, measured as the current replacement value of buildings and contents, is at risk of flooding from a 100-year event.
- Require approximately 1,100 miles of new or modified coastal protection structures on the Pacific Coast and San Francisco Bay to protect against coastal flooding. The total cost of building new or upgrading existing structures is estimated at about $14 billion (in year 2000 dollars.
- Result in a loss of 41 square miles of California's coast by 2100 due to accelerated erosion.

The California Coastal Commission (http://www.coastal.ca.gov/climate/climatechange.html) identifies the following six areas of concern for climate change in the coastal zone:

1. Storms and Flooding
2. Coastal Erosion and Loss of Sandy Beaches
3. Coastal Habitats
4. Marine Ecosystems
5. Land Use Planning Decisions
6. Shoreline Access

In this section consideration will be given to the following sub-sectors of Ocean and Coastal Resources:

- Coastal dependent infrastructure and land uses: Infrastructure and land uses that generally must be located near or on the ocean for functional or operational reasons.
- Coastal development: Existing and proposed residential, commercial, industrial, and public facilities development.
- Recreational resources and shoreline access: Parks, beaches, and shoreline access points.
- Water supplies: Surface and groundwater sources for municipal supplies.
- Fisheries operations and facilities: Fisheries and associated operations and facilities such as aquaculture areas and processing facilities.
- Coastal habitats: dunes, wetlands and estuaries, littoral zone habitats, near-shore marine ecosystems and other coastal habitats.

### 6.2.1 Exposure

- There are three climate change impacts that will affect this sector: sea-level rise (SLR), changed storm frequency and severity, and ocean acidification. The California Climate Change Center (2009, p. 49) estimates that sea level is "likely to increase by up to 35 inches by 2100, depending on the magnitude of climate warming." The world's oceans have experienced approximately 0.12 inch of SLR over the past decade. This rate is expected to increase as the 2100 forecast year is approached; thus, SLR will appear to be a relatively slow moving phenomenon through the first part of the century and then accelerate during the latter half. With SLR are the following associated effects:
- Inundation/long-term waterline change
- Extreme high tide
- Coastal erosion and loss of sandy beaches
- Salt water intrusion

In addition to SLR, "climate models project two important trends: higher sea level extremes resulting from increasing storm intensity and more frequent extreme events" (CCCC, 2009, p. 50). The combination of SLR and potential increased storm frequency and severity is problematic: "Most severe impacts result from the coincidence of sea-level rise with storm surge, tides, and other climatic fluctuations (like El Niño)" (CCCC, 2009,p. 500).

Cal-Adapt shows maps of inundation areas for the 100-year storm using data from the Pacific Institute and the United States Geological Survey (USGS). The maps show the current 100-year storm inundation as well as inundation scenarios for 19 inches (low GHG emissions), 39 inches (medium GHG emissions), and 55 (medium-high GHG emissions) inches of SLR by 2100.

Ocean acidification remains an area that is not fully understood. Although there has been a measured increase in the acidity of the world's oceans including California coastal waters, less is known about local variability and the effect this may have on coastal and ocean resources. With acidification, oceans have the potential to "to deteriorate to conditions detrimental to shell-forming organisms, coral reefs, and the marine food chain, thus threatening fisheries and marine ecosystems generally" (Pew Center on Global Climate Change, 2009, p. 1). Ocean acidification is not addressed in further detail in the APG, but coastal jurisdictions that depend on fisheries (especially shellfish) should be aware of the issue.

One last exposure issue to consider is the potential for changes in inland rainfall. Coastal flooding, especially in bays, estuaries, and river mouths, could be exacerbated due to changes in rainfall or Sierra snowmelt. Cal-Adapt provides maps showing potential changes in rainfall. Coastal communities can examine expected changes within upstream watersheds.

## 6.2.2 Sensitivity

There are numerous assets and resources that should be considered when assessing the potential impact of climate change in the coastal zone. Planners should assess the following:

- Coastal-dependent infrastructure and land uses
- Coastal development (existing and proposed)
- Recreational resources and shoreline access
- Water supplies
- Fisheries operations and facilities
- Coastal habitats

### Coastal-Dependent Infrastructure and Land Uses

Assessment of sensitivity should include the inventorying and mapping of the following types of assets: piers, marinas, moorings, breakwaters/seawalls, ports and related facilities, boat launches/ramps, oil gas facilities, aquariums, tourist areas, shipyards, coastal-related business and industry, wastewater treatment plants (WWTPs), and power plants. For those assets under control of the local jurisdiction—such as WWTPs—additional analysis should include an examination of the vulnerability to flooding/inundation of each asset based on its elevation, flood-proofing, and other factors. This should be coordinated with the department or agency that manages the asset. For assets not under the control of the local jurisdiction, appropriate outreach efforts should be conducted to encourage the owners/operators of those assets to consider the vulnerability to sea level rise.

### Coastal Development

Assessment of sensitivity should include the inventorying and mapping of existing and proposed residential, commercial, industrial, and public facilities development within the potential inundation zones. The inventory should also draw on U.S. Census or similar local data to identify populations that are especially vulnerable. If possible, the inventory should include the economic value of these land uses for use in economic impact assessment.

### Recreational Resources and Shoreline Access

Assessment of sensitivity should include the inventorying and mapping of coastal recreational resources and shoreline access points. Local, state, and federal agencies that manage these resources should be contacted for information regarding vulnerability assessments and adaptive practices.

### Water Supplies

Assessment of sensitivity should include the inventorying of surface water and groundwater supplies within the inundation zone and within the area susceptible to salt water intrusion. The assessment should be coordinated with the water provider. The discussion of water management included as part of Section 6.3 provides additional detail on this impact.

### Fisheries Operations and Facilities

Assessment of sensitivity should include the inventorying of fisheries operations and facilities such as aquaculture areas, processing facilities, and other related facilities not covered in the previous areas. Local jurisdictions should encourage owners/operators of those assets to consider the vulnerability to sea level rise.

### Coastal Habitats

Assessment of sensitivity should include the inventorying and mapping of dunes, wetlands and estuaries, littoral zone habitats, and other coastal habitats. Special attention should be paid to habitat areas with species listed by federal or state agencies for protection. In communities with these habitat areas, it is critical that biology and conservation staff play key roles on the climate adaptation team to accurately identify the aspects of these habitats potentially sensitive to projected changes.

## 6.2.3 Potential Impact

### Coastal-Dependent Infrastructure and Land Uses

Coastal-dependent assets cannot usually be moved away from the coast. Thus, jurisdictions will need to consider how effectively these assets may continue to function when exposed to the increasing number and severity of coastal storms and high tides, associated erosion, and potential long-term inundation. The periodic or permanent failure of these assets may compromise community safety and local economies.

Of particular concern to local communities should be wastewater treatment plants (both the plants themselves and their operations), as well as the ocean outfall facilities. Without adequate advance planning, the expense of armoring or relocation of these facilities could place a tremendous burden on local governments.

An additional concern is the potential economic impact if these assets are compromised, especially where the assets make up significant portions of the local economic base. Many California communities depend on tourism as a key part of their economies. Many coastal-dependent uses such as hotels, restaurants, and entertainment facilities generate tourist tax dollars.

### Coastal Development

The effect of coastal storms and erosion on coastal development, especially residential uses, is already a problem in California. The “armor vs. retreat” debate is a difficult one that involves regulatory agencies and the courts. Jurisdictions with coastal development will see this problem exacerbated and should focus on identifying existing structures at risk and planned structures that may be at risk if built.

### Recreational Resources and Shoreline Access

Recreation resources tend to be less capital-intensive than the assets described above. They primarily consist of parking areas, bathrooms, trails and stairs, boardwalks and overlooks, and moderate recreational amenities. Jurisdiction will need to consider the potential effect of SLR on these assets, but there is a more insidious problem that will require additional consideration. If there is coastline retreat (i.e., erosion and/or loss of sandy beaches), the public may experience the loss of the key amenity itself: access to the ocean and the beach. Jurisdictions should consider the number, size, quality, and distribution of beach and coastal recreation areas and the possibility that these qualities will be changed or diminished with SLR. These impacts will also be related to the tourism-related economic impacts discussed above.

### Water Supplies

Salt water intrusion may increase in coastal areas that experience more frequent and severe inundation. Jurisdiction should work with geologic and hydraulic specialists to determine the potential effect on groundwater supplies.

### Fisheries Operations and Facilities

The issue here is similar to the issue described for coastal-dependent infrastructure and land uses. In addition, aquaculture activities within or near the ocean and estuaries may be affected by SLR and coastal storms.

### Coastal Habitats

As SLR advances, it will force a migration or succession of coastal habitats. Of particular concern will be habitat areas that are small, isolated, and/or of poor quality. These factors will exacerbate impacts since they will restrict the ability of species to migrate or adjust to changing conditions. In addition, particular attention will need to be given to impacts on critical habitat or listed species.

## 6.2.4 Adaptive Capacity

Jurisdictions should review their current policy and program documents and coordinate with owners/operators of other assets and resources to determine what capacity currently exists to adapt to the consequences of SLR and coastal storms. Questions to ask include the following:

### General Questions

- Are there currently plans to strengthen or relocate assets and facilities? Is funding identified for implementation of these plans? Of particular interest are:
  - General plans (and associated implementation plans/ordinances)
  - Local coastal plan (LCPs)
  - Local hazard mitigation plans (LHMPs)
- Do regulations exist that seek to reduce or eliminate impacts?
- Have alternatives been identified for assets and facilities that cannot be strengthened or identified?
- Do alternative technologies exist that may support adaptation?
- For assets and facilities that generate social or economic benefits, do alternatives or substitutes for these benefits exist?
- What external resources or agencies exist to assist in adaptation?
- What is the current position of state agencies that may support or impede adaption actions? Of particular importance are the California Coastal Commission, California State Lands Commission, California Department of Fish and Game, California State Parks, State Water Resources Control Board, and California Public Utilities Commission.

## Questions Regarding Coastal-Dependent Infrastructure and Land Uses

- Are these uses necessary or needed? Does the community depend on these uses?
- Can these uses be protected or relocated within the coastal zone? What resources would be needed to do so? Do these resources exist and are they available?
- Is it possible to relocate any of these uses outside of the coastal zone?
- How prepared are owners/operators to deal with the impacts of climate change?

## Questions Regarding Coastal Development

- Can the development be protected or relocated? What resources would be needed to do so? Do these resources exist and are they available?
- De regulations exist to control future development to reduce risks?
- How prepared are the owners to deal with the impacts of climate change?
- Will the demographic/social/economic characteristics of the owners and residents impede adaption activities?

## Questions Regarding Recreational Resources and Shoreline Access

- Can the resources be protected or relocated? What resources would be needed to do so? Do these resources exist and are they available?
- What is the capacity for beach protection and renourishment?

## Questions Regarding Water Supplies

- How dependent is the community on these supplies?
- Are there available substitute supplies (including conservation)? What resources exist to obtain the alternative supplies?

## Questions Regarding Fisheries Operations and Facilities

- Are these operation and facilities necessary or needed? Does the community depend on these?
- Can the resources be protected or relocated? What resources would be needed to do so? Do these resources exist and are they available?

## Questions Regarding Coastal Habitats

- How unique are these habitats?
- Can the habitats be recreated elsewhere? Are adequate sites available and can or does the jurisdiction have access to these sites?
- Are there species already vulnerable (endangered or threatened) that may be further stressed by the projected changes?
- Are there existing plans or policies protecting and/or promoting vulnerable habitats?

### 6.2.5 Onset and Risk

The Intergovernmental Panel on Climate Change (IPCC) considers SLR to be of high probability; therefore, coastal communities should consider the potential impacts of SLR to be of higher priority for adaptive planning than other potential effects of climate change.

The current rate of SLR over the last decade is about 0.12 inch per year. Thus, the current onset of SLR is relatively slow. The rate is expected to increase closer to the 2100 forecast year.

SLR is almost certainly coming, but local jurisdictions have time to implement adaptation strategies. Planning should start now and implementation should be timed to meet the expected onset of the effects of SLR. Coastal jurisdictions should keep in mind that many issues, such as coastal storms, erosion, and loss of sandy beaches, are currently a problem, and that the sooner action is taken the sooner it can resolve both current problems as well as the expected future ones.

**Additional Resources**

- State of California Sea-Level Rise Interim Guidance Document (October 2010). Developed by the Sea-Level Rise Task Force of the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT), with science support provided by the Ocean Protection Council's Science Advisory Team and the California Ocean Science Trust. http://www.opc.ca.gov/2011/07/sea-level-rise-task-force-interim-guidance-document/
- California Coastal Commission. Global Warming and Climate Change web resources. http://www.coastal.ca.gov/climate/climatechange.html
- San Francisco Bay Conservation and Development Commission (BCDC). Climate Change web resources. http://www.bcdc.ca.gov/planning/climate_change/climate_change.shtml
- The San Diego Foundation & ICLEI. Sea Level Rise Adaptation Strategy for San Diego Bay (January 2012). http://www.icleiusa.org/climate_and_energy/Climate_Adaptation_Guidance/san-diego-bay-sea-level-rise-adaptation-strategy-1/san-diego-bay-sea-level-rise-adaptation-strategy

## 6.3 Water Management

The water management sector addresses flooding and water supply in communities. Both of these areas may be affected by climate change. Although the scientific evidence regarding increased flooding related to climate change remains uncertain, it is prudent for communities to recognize that changes in precipitation regimes and the rate and timing of snowmelt may affect flooding conditions. Water supply is expected to be affected in areas that experience less precipitation and areas dependent on snowpack. Flood and water supply issues are described separately below, but given the interrelated nature of water management for most communities, it is recommended that climate adaptation strategies address these issues together.

### 6.3.1 Flooding

California's diverse geography, including coasts, coastal and inland mountains, valleys, and highly varied and distinct desert regions, creates the potential for a variety of flood types: alluvial fan, coastal, flash, fluvial, lake, levee, mudslide, and riverine. Secondary impacts include flooding, erosion, and debris flows that may occur during the months and years following wildfires.

Flooding is a very real and growing threat within most regions and deserves careful attention as one of the more deadly potential impacts of climate change. Although climate change is leading to declining precipitation in some parts of California, it is also generating increasingly severe storms that exacerbate flooding. Additionally, earlier Sierra snowmelt is leading to heavier spring flooding, especially in the Central

Valley. Conversely, declining precipitation and long-term reductions in snowpack will yield less flooding in other areas, such as desert regions. These impacts affect the frequency and severity of flood hazards in many regions of California.

The impacts must be interpreted on a regional and local watershed basis in relation to factors such as types of terrain, overall gradients of the watercourses, levels of development and impervious surfaces, degree to which human settlements are located in flood-prone areas, and the flood management systems that are in place or planned. Changes in flow regimes also affect biodiversity and aquatic ecosystems, as addressed in Section 6.7, Biodiversity and Habitat, below.

Thus, there are no "one-size-fits-all" flood management strategies suitable for the entire state. Adaptation strategies and flood management solutions will necessarily be highly localized within each region and watershed. The map below shows that many areas of the state – including populated areas in the Central Valley – are vulnerable to flooding.

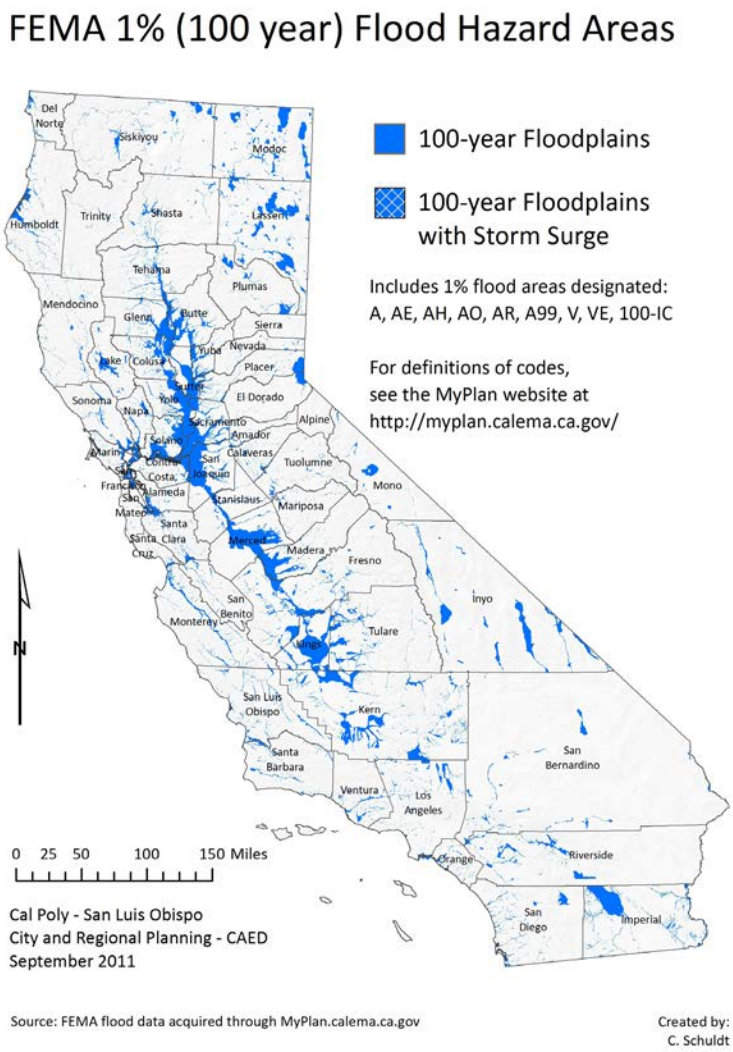



Figure 7. FEMA 100-year Flood Hazard Areas.
Source: California 2010 State Hazard Mitigation Plan Executive Summary

FEMA and DWR flood hazard maps are now available statewide on MyPlan, a web-based GIS map service sponsored by the California Emergency Management Agency (Cal EMA) and the California Natural Resources Agency (http://myplan.calema.ca.gov/). MyPlan provides one-stop access to flooding, wildfire, and earthquake information provided by separate agencies.

## Exposure

Climate change impacts directly affecting flooding and flood management during the 21st century are likely to include the following:

- Possible precipitation decreases ranging from 12 to 35 percent compared to historical averages, depending upon location;
- More winter precipitation falling as rain instead of snow; and
- Intense rainfall events leading to more frequent and/or more extensive flooding (CNRA, 2009)

Climate change impacts interact; this, too, has consequences for flood risk. Specific Cal-Adapt guidance and data important for assessing exposure in a given region include three separate climate change factors: (1) precipitation trends, (2) snowpack scenarios, and (3) wildfire projections. Cal-Adapt mapping shows a general redistribution of heavy precipitation away from southern and inland hydrologic regions and toward central and northern regions.

Substantial reductions in snowpack in coastal and northern mountains as well as the Sierra Nevada range are expected to be accompanied by earlier rainfall and runoff downstream, most particularly in the Sacramento River and San Joaquin River watersheds, which converge in the California Delta. When combined with the continued northeastward flow of moisture-laden air from tropical zones from the Central Pacific depositing more rainfall in the northern portions of the state, these trends suggest the possibility of more intense flooding in the northern and central portions of the Central Valley as well as the San Francisco Bay region.

Adding to these factors are Cal-Adapt projections in these same mountainous regions that show substantial increases in wildfire. According to the 2010 State Hazard Mitigation Plan, "…Wildfires greatly reduce the amount of vegetation, which in turn reduces the amount of rainwater absorption, allowing excessive water runoff that often includes large amounts of debris, dirt, and other sediments… Periods of high intensity rainfall are of particular concern, but post-fire flooding can also occur during a normal rainy season" (Cal EMA, 2010, pp. 198-199).

A key question for assessing exposure is how different climate change impacts might be in relation to current conditions. Although overall projections for total annual precipitation show little change, trends vary substantially by region and are considered uncertain. Taken together, however, the preceding factors suggest that northern portions of the state, especially the Central Valley, are more likely to experience increased and more widespread flooding in the remainder of the century.

The Central Valley is ripe for more frequent and/or more extensive flooding due to climate change factors cited previously as well as existing patterns of development in flood-prone areas. By comparison, heavily developed areas of Los Angeles and San Diego counties that are equipped with extensive, hardened flood control systems that carry storm flows rapidly to the ocean are more vulnerable to increased landslide and mudflow risk in hillside areas in the aftermath of major wildfires experienced in the past decade (Cal EMA, 2010).

Regions that experience substantially wetter conditions due to heavier rainfall and earlier snowmelt can expect to have more pressure placed on flood management systems of all kinds. When combined with sea level rise and intensification of coastal surge and erosion, riverine flooding along low-lying coastal areas will back up into inland areas, creating new floodplains and the need for adaptation of both flood control and flood management systems.

The standard references for establishing location of flood hazards throughout the nation are the Flood Insurance Rate Map (FIRM)-designated floodplains, part of a national insurance system maintained under the National Flood Insurance Program (NFIP). The FIRM maps identify standard flood hazard zones for insurance and flood management purposes and provide a statement of probability of future occurrence based on past experience.

Flood zones are areas depicted on a FIRM map defined by FEMA according to levels of risk. FEMA publishes and maintains 500-year and 100-year FIRM maps under NFIP. For example, a flood of a magnitude recurring on an average of every 500 years has a 0.2-percent chance of occurring in any given year. A flood of a magnitude recurring every 200 years has a 0.5-percent chance, and a flood of a magnitude recurring every 100 years has a 1-percent chance. Zones with a 1-percent annual chance of flooding are considered to have high risk.

The California Department of Water Resources (DWR) is developing 200-year (0.5-percent) flood maps for the Central Valley and other regions. Based on bond proposals (Propositions 1E and 84) passed by voters in 2006, DWR has been preparing maps showing the 200-year flood areas in the Central Valley (Sacramento River and San Joaquin River drainages) under its FloodSAFE program.

Such recurrence intervals represent the long-term average periods between floods of specific magnitudes; significant floods can occur at shorter intervals or even within the same year. Note also that recurrence intervals for currently published floodplain maps reflect probabilities based on past experience and do not take into account anticipated climate change impacts.

Unfortunately, information on local-level changes in flooding does not exist. Analysts will have to consider their community's current flood risk in light of the expected climate changes described above. FEMA flood maps could be considered to be conservative estimates of exposure to potential floods; thus, communities may want to consider 200-year and 500-year floodplains when developing flood policies and programs.

## Sensitivity

There are numerous assets and resources that should be considered when assessing the potential impact of climate change on flooding. Planners should assess the following:

- Flood/stormwater management infrastructure and systems
- Development and infrastructure within floodplains (100-, 200-, and 500-year), especially:
  - Critical facilities
  - Lifeline infrastructure including bridges, tunnels, major roads

Assessment procedures to determine sensitivity of flood management systems should be centered primarily on extension of GIS mapping to more completely identify existing and potential flood-prone areas.

Greater collaboration among FEMA, DWR, regional flood control districts, and local governments will be needed not only for evaluation of local sensitivity to climate change flooding exposures, but also for devising more adaptive solutions.

## Potential Impact

Climate change impacts on flooding and flood management systems are cross-cutting, affecting community resources, functions, and populations in similar ways. Most directly affecting these impacts are the manner in which land uses within individual communities, watersheds, and regions are overlaid on flood-prone areas. Extensive below-sea-level areas with exceedingly poor drainage have the propensity to retain flood waters for extended periods of weeks or months, interrupting transportation and hurting local commerce. With a serious Delta levee break, business recovery would become problematic for an extensive period, and conveyance of waters originating in the northern regions of the state to the people living in southern regions of the state via the State Water Project would be seriously interrupted, injuring the entire state's economy.

**Community Resources and Functions.** Residential, commercial, and industrial areas together comprise the predominant uses of land in human settlements, interspersed with infrastructure and open spaces needed to support these activities. Access to flowing streams as a water source is a historical reason why so many cities are overlaid directly on flood-prone areas.

Sensitivity of community resources to climate change flooding impacts generally can be assessed in relation to the degree to which individual communities are either built out or have future growth potential. Built-out communities have little choice but to retrofit existing neighborhoods either by intensifying flood control systems, elevating existing development above base flood elevations, or buying out existing homes for open space.

Many older communities, such as Los Angeles or San Luis Obispo, have downtowns located adjacent to their original water sources, with accompanying flood hazards, risks, and vulnerability. In many communities, this has necessitated after-the-fact construction of channels and culverts to divert storm flows around and under previously developed areas.

**Identifying Flooding Impacts.** Examples of steps for assessing particular flooding impacts include (1) assessing older vs. newer neighborhoods, and (2) using a community climate adaptation team.

Flooding impacts generally are not linked to specific populations, such as seniors, children, or individuals with disabilities. However, older housing inventories are sometimes located in low-lying, more flood-prone areas near where the community was originally established. In such areas, there may tend to be greater concentrations of renters, elderly, and minorities, and such neighborhoods are likely to be more greatly affected by historical flooding than newly suburbanizing communities. In growing communities, wiser land use decisions that avoid placing residential, commercial, industrial, and infrastructure development in flood-prone areas can reduce future losses of life and property and conserve expenditure of public funds for buy-outs. It can also minimize climate change flooding impacts on specific populations living in

growing communities.
Determination of climate change flooding impacts can be more carefully completed through use of a community climate adaptation team. In cases with vulnerable populations, the team should include representatives of potentially affected population groups and should use MyPlan and other GIS map services to identify where flood hazard areas and vulnerable populations overlap. Equally of concern is assessment of variable flooding impacts on business continuity.

**Flood Management Systems.** Climate change impacts have a very direct effect on flooding and flood management systems. Flood control systems currently in place may eventually prove insufficient to handle flows generated by strong episodic rainfall in regions that are becoming drier, as well as those that are becoming wetter.

Southern regions that can expect substantially drier conditions may experience both less regular and more episodic flooding. Declining overall precipitation within such regions may be accompanied by occasional intense storms, creating flood events as damaging as in the past, or even more so. When combined with unanticipated wildfires, such events can place great pressure on flood control systems. Likely outcomes are greater flooding and related losses (e.g., from mudslides).

A highly publicized example of pressure placed on flood control systems in post-wildfire areas was the aftermath of the devastating August 2009 Station Fire. The fire started in the Angeles National Forest above La Canada Flintridge and burned over 250 square miles, leading to the deaths of firefighters and evacuation of thousands of homes. The Station Fire was followed in the winter by severe mudflows that quickly overflowed debris basins built in the early 1900s and quickly inundated dozens of homes and closed many streets. Re-engineering and reconstruction of check dams to improve capacity would be costly and take many years.

Beyond the current state of flood control systems is the presence in many FEMA flood zones of large numbers of people due to prior development in the floodplain. According to the 2010 State Hazard Mitigation Plan (Cal EMA, 2010, p. 207):

> Studies comparing 2000 U.S. Census data with NFIP FIRM maps found that over 5 million Californians (15 percent of total population) lived in a FIRM-designated floodplain and nearly 2 million (5.8 percent of total population) lived in the 100-year floodplain. Based on these studies, California would normally expect approximately 20,000 people per year to be affected by 1 percent and 0.2 percent annual flooding; however, the state's flood risk is not evenly distributed. Approximately 84 percent of the 5 million Californians living in a FIRM-designated floodplain were in 13 counties having 100,000 or more people within 100-year and 500-year FIRM-designated floodplains (see Table 5.U). In 2000, the leader by far was Orange County, with 1.4 million people at risk.

Collaboration for evaluation of climate change flooding impacts should include not only technical staffs of federal and state agencies (FEMA, Cal EMA, and DWR) but also, at the local level, broadened participation of vulnerable populations that are stakeholders in climate adaptation planning.

## Adaptive Capacity

Jurisdictions should review their current policy and program documents and coordinate with owners/operators of other assets and resources to determine what capacity currently exists to adapt to increased flooding.

**General Questions.**

General questions to ask include the following:

- Are there currently plans to strengthen or relocate community assets or to improve flood/stormwater management infrastructure? Is funding identified for implementation of these plans? Of particular interest are:
  - General plans (and associated implementation plans/ordinances)
  - Capital improvement plans
  - Local coastal plans (for coastal jurisdictions)
  - Local hazard mitigation plans (LHMPs)
  - Actions taken in response to SB 5 and 17 and AB 5, 70, 156, and 162
- Do regulations exist that seek to reduce or eliminate impacts, such as floodplain development ordinances?
- Have alternatives been identified for assets and facilities that cannot be moved or strengthened?
- Do alternative technologies exist that may support adaptation?
- For assets and facilities that generate social or economic benefits, do alternatives or substitutes for these benefits exist?
- What external resources or agencies exist to assist in adaptation?
- What is the current position of state agencies that may support or impede adaption actions? Of particular importance are the California Coastal Commission, California Fish and Game, and State Water Resources Control Board.

An important variable determining local adaptive capacity in the future is the manner in which communities have previously dealt with flooding. Cities, counties, and flood control districts that have created extensive networks of concrete-lined channels are already faced with the dilemma of raising or spreading channel walls to accommodate heavier flows, on the one hand, and softening channel bottoms to better meet federally mandated environmental requirements, on the other.

Parallel to that are situations where flood management and/or land use planning has ignored the existence of floodplains, allowing development in areas where flooding is already recurring in 10- or 20-year return periods and repetitive damages and loss of life are already costly.

**Questions Regarding Factors Affecting Adaptive Capacity.**

Other basic factors affecting the capacity of communities to devise suitable adaptation strategies counteracting climate change-induced flooding include the following:

1. Built-out communities: existing vulnerabilities to flooding – i.e., how bad is flooding under present-day conditions?
2. Growing communities: availability of options for managing future flooding impacts – i.e., what choices does the community have to avoid further aggravation of existing flood vulnerabilities?
3. Governance: local government capabilities for addressing adaptation through informed public policy supported by wide-ranging stakeholder involvement – i.e., to what extent is local decision-making informed by new climate change information and varying stakeholder perspectives?

Other factors include economic resources by which the community can fashion effective adaptation strategies, accessibility of information identifying locally relevant climate change impacts, availability of relevant skills and knowledge-sharing within members of the community, natural resources providing adaptation options, and resilient infrastructure.

In 2007 the California legislature passed and the Governor signed six interrelated bills aimed at addressing flood protection and liability and helping direct use of bond funds. These were Senate Bills (SB) 5 and 17 and Assembly Bills (AB) 5, 70, 156, and 162. Some of the requirements of the 2007 flood risk management legislation apply statewide, others are applicable to lands within the Sacramento-San Joaquin Valley, and others apply solely to lands within the Sacramento-San Joaquin Drainage District. For example, under SB 5, the Central Valley Flood Management Planning Program is being pursued to develop integrated, sustainable flood management for areas protected by state-federal flood protection systems in the Central Valley (http://www.water.ca.gov/cvfmp). A Central Valley Flood Protection Plan is being prepared for adoption by mid-2012.

AB 162 requires additional consideration of flood risk in local land use planning throughout California. The California Department of Water Resources (DWR) has prepared a guidance document that describes the new legislative requirements that affect city and county local planning responsibilities such as general plans, zoning ordinances, development agreements, tentative subdivision maps, and other actions. The document, entitled "Implementing California Flood Legislation into Local Land Use Planning: A Handbook for Local Communities" (available at www.water.ca.gov/LocalFloodRiskPlanning/), is intended to help cities and counties comply with the new legislation.

### Onset and Risk

The rapidity of onset and the probability of more intense or widespread flooding conditions are unknown at this time. The climate adaptation team should start with a solid understanding of the scope and extent of existing flood hazards as a precondition for probable intensification of risk.

## 6.3.2 Water Supply

Water supply consists of the water resources available for societal uses. Societal uses encompass agricultural irrigation and production, drinking water, urban landscaping, cooling, and power generation (steam turbines and hydropower). In California, water resources originate in the form of rain or snowfall and are spread among the Sierra snowpack, the state's water network (including streams, rivers, aqueducts, and reservoirs), and groundwater. The California Department of Water Resources Climate Change Handbook for Regional Water Planning (2011) provides extensive detail and guidance on climate and vulnerability assessment, including a list of vulnerability assessment questions. The questions fall into three primary areas of vulnerability: water demand, water supply, and water quality. Along with the growing population and the health of ecosystems, climate change is one of the major influences on the availability of water resources (Christian-Smith et al., 2011). The availability (or lack) of water influences agricultural output, ecosystem health, energy production, provision of basic community services, and water-reliant businesses and industries in the state.

The effects of climate change on water supplies will have impacts on agriculture, recreation and tourism, and the economy overall as well as on natural ecosystems. The environment (that is, the water needed to maintain ecosystems) accounts for 48 percent of water use in California, with agricultural use at 41 percent and urban

use at 11 percent. Due to projected population growth, however, urban use is expected to increase more than 50 percent by the year 2050 (Kahrl and Roland-Host, 2008).

## Exposure

Climate change threatens several aspects of a community's water supply. It can affect the source of a community's water (e.g., Sierra snowpack, California Delta, or groundwater aquifer) as well as a community's use behavior. Several direct climate impacts – particularly temperature and precipitation variation – affect water availability. For coastal communities, sea level rise can threaten groundwater resources due to sea water intrusion. Assessing exposure to climate change impacts requires a community assess not only local conditions, but also the projected conditions for their water source.

If a portion of a community's water supply comes from snowmelt, the analyst should examine the Cal-Adapt forecast for changes in snowpack. On a seasonal basis, water scarcity will become far more common, as the Sierra snowpack is projected to shrink at least 30 percent and as much as 80 percent by 2099 (Kahrl and Roland-Host, 2008). While water flow will actually increase in winter – due to more precipitation falling as rain instead of snow and to snow melting more quickly – summertime flow will decrease. Therefore, more water will be available in winter when demand is lowest and less will be available in summer when demand is greatest. Seasonal variability in water availability will also reduce the state's hydropower supply, which, in 2007, accounted for 14.5 percent of the state's total power (Kahrl and Roland-Host, 2008). Additionally, drought frequency is likely to increase by a factor of 2.5 under "dry" climate projection scenarios (Luers et al., 2006).

If a portion of a community's water supply comes from surface reservoirs supplied by rainfall, then the analyst should examine the Cal-Adapt information on expected changes in rainfall.

If a portion of the community's water supply comes from coastal aquifers, then the analyst should examine the Cal-Adapt information on sea level rise to determine if salt water intrusion could become a problem. Climate change will lead to sea level rise and encroachment of salt water into coastal groundwater aquifers, further affecting water supply.

In addition to the above, if a portion of a community's water supply comes from the California Delta (delivered by one of the systems of aqueducts), the analyst should refer to the region focused specifically on the Bay-Delta.

## Sensitivity

Resilient resources are those able to withstand a higher degree of climate change. Sensitive water supply sources are those most in need of adaptation planning to add resilience that is currently lacking. To assess the extent of climate change impacts on water supply, communities should consider the following questions (adapted Appendix B of the Handbook – available at http://www.water.ca.gov/ climatechange/docs/Appendix%20B%20 Vulnerability%20Assessment%20Checklist-Final.pdf):

- Does water demand vary by more than 50 percent seasonally in your community?
- Does your community rely on a large percentage of groundwater? If so, is additional groundwater pumping necessary during drought years?

- If crops are grown in your region, are they sensitive to climate variation (especially drought and extreme heat)?
- Are there any major industries in your community that require water for cooling or as part of their process?
- Are there vulnerable populations occupying buildings that rely on water for cooling (such as schools, hospitals, senior homes, and low-income housing units)?
- Are there recreational water uses that cannot always be met due to water quantity or quality issues?
- Does your community's water quality shift during rain events that in a way that affects water treatment facility operation?

## Potential Impact

Communities may want to consider employing the California Department of Water Resources Climate Change Handbook for Regional Water Planning (2011) to evaluate the impact of climate change on water supply, especially if the water supply is very exposed or sensitive.

**Surface Water Supplies.** Communities with water supply sources that will experience reduced rainfall or snowpack will likely see a long-term reduction in the amount and reliability of those sources. Water supply shortages are nothing new to most California communities; therefore, the impacts of climate change will not create a novel problem.

**Coastal Aquifers.** Communities with coastal aquifers may be subject to sea water intrusion, especially in aquifers with high pumping rates. Communities should assess current levels of intrusion and employ specialists to determine how sea level rise may affect the rate.

## Adaptive Capacity

Adaptive capacity is a community's ability – through its plans and implemented policies – to effectively react to or reduce the magnitude of climate change. Jurisdictions should work with the owners, operators, and major consumers of water resources to learn what current capacity exists to deal with climate change impacts. Questions to ask include:

- Does the community have proven and effective emergency water curtailment measures for droughts?
- What is the community's drought readiness?
  - Has the community faced a recent drought in which water demands could not be met?
  - Is your water system able to store and keep surpluses?
- Does the community have a local and/or regional Urban Water Management Plan?
  - Are the measures in this plan adequate given projected supply and use demand?
- Does the community have existing policy (general plan, programs, ordinances) to promote or mandate demand management (e.g., water efficiency)?

## Onset and Risk

Rainfall projections through the end of the century vary widely depending on the climate model used. However, all of the models used on Cal-Adapt show a significant decline in the Sierra snowpack through the year 2090, which will result in a reduction of stored water throughout the state. The IPCC has established changes in precipitation as medium probability (table 2).

**Additional Resources**

- California Data Exchange Center: http://cdec.water.ca.gov/
- This Department of Water Resources site provides various statewide and regional water data, covering water supply, river flow levels, snow levels, and projected runoff.
- California Irrigation Management Information System: http://wwwcimis.water.ca.gov/cimis/welcome.jsp
- This database from DWR's Office of Water Use Efficiency allows users to generate reports on temperature, precipitation, and evapotranspiration.
- California Water Plan Update 2009: http://www.waterplan.water.ca.gov/cwpu2009/index.cfm
- The State Water Plan collects water supply and use data in the Regional Reports (Volume 3 of the plan). Additionally, the appendix includes the raw data sources for the State Water Plan, found here: http://www.waterplan.water.ca.gov/technical/datasources/index.cfm
- Water Data Library: http://www.water.ca.gov/waterdatalibrary/index.cfm
- DWR's interactive map application enables users to find local data on groundwater use, water quality, and water flow.

## 6.4 Forest and Rangeland

While wildfire is a critical ecosystem process in much of California, climate change is expected to contribute to increases in fire frequency, size, and severity beyond the historic range of natural wildfire variability. In general, more frequent, larger, and higher-severity fires have been predicted due to increasing length of the fire season, drier fuels, and decreasing forest health. These changes are being driven by alterations in temperature and precipitation regimes (generally, warmer and drier). Under various GHG emissions scenarios, climate change is predicted to result in substantial increases in both fire occurrence and area burned, with especially acute increases in mid-elevation forests of the Sierra Nevada, the northern California coast, and the southern Cascade Ranges (Westerling et al., 2009).

The influence of climate change on wildfires in California, however, is variable and extremely complex. In general, wildland fire behavior is the result of the interactions of fuels, weather during the event, and topography. Thus, climatic shifts may induce not only changes in weather (via wind, temperature, relative humidity, etc.), but also wildland fuels (via fuel type, amount, moisture, etc.), which subsequently will influence fire number, size, and severity. In addition, impacts depend upon a myriad of interacting factors including geographical region, ecotypes within a region (as influenced by elevation, aspect, etc.), past land management, future demographic shifts, past and future wildfires, suppression infrastructure and effectiveness, and others.

The vast majority of annual acreage burned in California is caused by a small percentage of fires that occur during extreme fire weather events that inhibit successful suppression, especially in chaparral ecosystems (Moritz, 1997). Climate change will likely increase the number of days in which large, high-intensity fires are expected. Indeed, mean temperatures and temperature extremes are increasing throughout California and are predicted to increase between ~2oC and ~6oC by the end of the century (Cayan et al., 2006), which will influence fuel type and fuel moisture. Predictions in precipitation patterns vary (Cayan et al., 2008); while less change is predicted in mean annual precipitation in many parts of California, there is expected to be greater fluctuation between years and decades (Cayan et al., 2006). Also, many areas are predicted to have less snow and more rain (Anderson, 2008; Mote, 2005); this change translates into longer periods without moisture,

which in turn strongly influence fuel moisture and subsequent fire potential and behavior. Further, climatic shifts could influence ignitions via lightning (Price and Rind, 1994; Lutz et al., 2009) and also winds (Miller and Schlegel, 2006) that facilitate large, high-intensity fires.

### 6.4.1 Exposure

Climate change impacts on temperature and precipitation regimes will drive multiple factors that influence habitat structure, fuel moisture, and subsequent fire risk.
Cal-Adapt is one source that can aid a community in understanding its exposure to climate change effects. Cal-Adapt shows increase in fire risk relative to 2010 for 2020, 2050, and 2085. When evaluating Cal-Adapt data, the degree of change from current conditions is a critical aspect of understanding potential exposure to climate change. The change is measured in averages and totals, but seasonal changes may be equally important. In addition to the fire risk information, Cal-Adapt allows for average high and low temperatures to be evaluated on a monthly basis. Changes in the seasonal temperature pattern will affect vegetative and moisture conditions.

Communities will also need to have a clear understanding of the surrounding habitat and health, as well as topography in relation to fire behavior. These factors are not addressed in Cal-Adapt.

### 6.4.2 Sensitivity

While fire is an important part of ecosystem function, it can create problems in areas of human settlement. Climate change may alter the frequency, size, type, and severity of wildfire events. Planners and policy-makers should assess the fire sensitivity of the following community assets:

- Development at the wildland-urban interface (existing and proposed)
- Forest- and rangeland-reliant industries
- Forest and rangeland ecosystems

#### Development at the Wildland-Urban Interface (Existing and Proposed)

Assessment of sensitivity should include an inventory of existing and proposed development (residential, commercial, industrial, and public facilities) in terms of adjoining habitat type, topography, and level of access. This inventory should also include the building materials, condition, and form (e.g., wood shingles or decks). These factors influence the level to which structures can withstand potential impacts such as fire, landslide, or erosion. The economic value of these areas and populations that live and/or work in the interface areas should also be assessed. The populations should be evaluated to identify individuals who may be particularly vulnerable. In addition to development, assessment of sensitivity should include the inventory of infrastructure that is in or near the wildland-urban interface. The inventory should also note what services are provided by the infrastructure and to whom. Special consideration should be given to infrastructure that may cutoff a critical link in an infrastructure systems such that it compromises the entire system. Given the need to move emergency equipment and personnel as well as the need to evacuate people during a fire event, transportation infrastructure is often one of the most critical community assets.

### Forest- and Rangeland-Reliant Industries

Communities should assess the potential impacts on the continuity and viability of commercial operations that rely on these ecosystems or that may be sensitive to potential climate change effects. The assembled climate adaptation team should include representatives of these businesses and work with them to identify risks and incorporate climate change into their management plans.

### Forest and Rangeland Ecosystems

Assessment of sensitivity should include the inventorying and mapping of regional forest and range habitats. Special attention should be paid to habitats at risk to change in type due to altered seasonal patterns and/or fire regimes. In addition, species listed for protection by state or federal agencies should be identified, particularly if their habitat is vulnerable to climate change impacts. This assessment relies on having local biologists and land managers as part of the adaptation team.

## 6.4.3 Potential Impact

### Development at the Wildland-Urban Interface (Existing and Proposed)

Although fire at the Wildland-urban interface (WUI) may already be a problem, climate change will exacerbate this problem in areas shown to have increasing wildfire risk. In areas with historically lower wildfire risk, development and infrastructure in the WUI may not have landscaping, building materials and designs, or proper siting to resist wildfire. Thus, the combination of increased risk and poor fire resistance may represent a new type or scale of impact for a community. Moreover, depending on the emergency response capacity (discussed below communities may not be capable of dealing with these impacts.

### Forest- and Rangeland-Reliant Industries

Changes in temperature, precipitation, and wildfire risk will change forest and rangeland productivity. Consequences for the forestry industry are likely to be slower growth, stressed trees, or insect epidemic. Some forests are at greater risk of stand-replacement wildfires that damage or destroy long-term investment while requiring post-fire planting, road maintenance, and other actions. It is possible, however, that some areas that are currently shut down each winter could see extended logging seasons .

The impact on livestock grazing is less clear. If precipitation decreases and/or temperature increases, then forage quantity could decrease. Livestock would experience increased heat stress and ranchers would likely have to increase water supply for livestock. Also, earlier curing of grasses would facilitate an earlier fire season in grasslands, putting forage at risk.

### Forest and Rangeland Ecosystems

There will likely be changes to species composition and distribution across the state, especially across elevational gradients. In areas where migration is restricted or adaptation cannot occur, species could be lost.

## 6.4.4 Adaptive Capacity

Jurisdictions should review their current policy and program documents, and coordinate with owners/operators of other assets and resources, to determine what capacity currently exists to adapt to changes in

wildfire regimes. Questions to ask include the following:

- Are there currently plans to strengthen or relocate assets and facilities? Is funding identified for implementation of these plans? Of particular interest are:
  - General plans (and associated implementation plans/ordinances)
  - Local hazard mitigation plans (LHMPs)
- Do regulations exist that seek to reduce or eliminate impacts?
- Have alternatives been identified for assets and facilities that cannot be strengthened or relocated?
- Have changes to emergency response resources and functions (especially suppression initial response) been identified?
- Do alternative technologies exist that may support adaptation?
- For assets and facilities that generate social or economic benefits, do alternatives or substitutes for these benefits exist?
- What external resources or agencies exist to assist in adaptation?
- What is the current position of state agencies that may support or impede adaptation actions? Of particular importance are CAL FIRE and the Department of Fish and Game.

Climate change will likely alter the effectiveness of suppression initial attack. Depending on location, current suppression activities may be adequate with minor adjustment for projected change. In other cases, more drastic change may be required. In one study of a forested area in the Sierra Nevada (Fried et al., 2006), researchers concluded that small increases in fire personnel and equipment could offset climate-induced increases in fire frequency and severity. However, this would necessitate active fuels management by prescribed fire or mechanical treatment, which is costly and triggers environmental regulatory scrutiny that may deter active pre-fire management in some areas. Added fire personnel and equipment may not significantly influence successful initial attack in more volatile fuel types such as Southern California chaparral, where fire agencies are currently extremely effective except in extreme weather events when suppression efforts are largely ineffective.

### 6.4.5 Onset and Risk

The IPCC has not established probabilities for change in wildfire risk. The Cal-Adapt wildfire model considers changes in precipitation and temperature, but the interaction of these is complex and dependent on other factors, particularly change in vegetation. The IPCC has indicated that changes in precipitation are “medium probability” and changes in temperature are “high probability” (table 2). Therefore, using the more conservative of the two, changes in wildfire regimes should be considered to be of medium probability. Since Cal-Adapt shows changes at 2020, 2050, and 2085, analysts can use this tool to examine the onset of impacts and the rate of change over time.

**Additional Resources**

- Cal Fire – Adaptation to Climate Change: http://www.fire.ca.gov/resource_mgt/resource_mgt_EPRP_Climate/climate_change_adaptation.php
- US Forest Service – Climate Change Resource Center: http://www.fs.fed.us/ccrc/
- Association for Fire Ecology – San Diego Declaration on Climate Change: http://fireecology.net/sandiegoclimatechange.html

## 6.5 Biodiversity and Habitat

California is home to a greater diversity of plants and animals than any other state (Steinhart, 1990). These species are part of the many ecosystems that can be found in California including forests, grasslands, wetlands, rivers, lakes, chaparral, deserts, mountain ranges, and many others (CNRA, 2009; CDFG, 2007; CDFG, 2011). These ecosystems are critical to the quality of life experienced in California, including clean water and air, food resources, recreation, economic opportunities, and safety from natural hazards (CNRA, 2009; CDFG, 2011). It is this rich setting that draws human settlement to the state, but the associated development stresses existing ecosystems through processes such as land use change, water allocation, and introduction of invasive species (CDFG, 2007). Over 20 percent of species native to California are classified as endangered, threatened, or "of special concern" by state or federal agencies (Steinhart, 1990; CDFG, 2011).

Climate change has the potential to further stress the native biodiversity and alter the conditions in existing ecosystems. Temperature and precipitation changes can result in habitat loss, species loss, alteration of the range and distribution of species, increased competition with non-native species, and disruption of ecosystem interactions such as pollinator and plant (Snover et al., 2007; CNRA, 2009). Other climate change impacts such as sea level rise, ocean acidification, and wildfire will also stress native species and alter ecosystem conditions. Not only do climate change impacts pose a risk to the biodiversity in the state, they will have detrimental economic impacts due to loss of ecosystem services. Climate change is estimated to place $2.5 trillion in assets at risk in California (CDFG, 2011).

The range of potential impacts resulting from climate change is as broad as the diversity of ecosystems in California. Climate change impacts on biodiveristy can be loosely divided into categories: species range, invasive species, community composition, hydrologic change, and disturbance regimes.

### 6.5.1 Exposure

The climate change impacts most likely to affect biodiversity and habitat are alterations in temperature, precipitation, and sea level rise. A secondary effect, wildfire, also has the potential to alter ecosystems and the species dependent on them.

A community assessing the extent to which climate change may affect local and regional ecosystems must first evaluate the projected changes to climate that may affect these ecosystems and the degree to which these changes differ from current conditions. Questions to ask include the following:

- What are the near-term, mid-term, and long-term projections for the following factors?
  - Temperature
  - Precipitation
  - Sea level rise
  - Wildfire
- To what extent do these projections differ from current conditions?

While climate models rarely project extreme event occurrence, communities should evaluate existing flood

maps (inland and coastal), acknowledging that floodplains may expand. Particular attention should be paid to low-lying areas adjacent to existing floodplains.

## 6.5.2 Sensitivity

The determination of sensitivity requires that a target be identified (i.e., what should be evaluated for sensitivity?) (Glick, Stein, and Edelson, 2011). Determining those habitats and species that may be sensitive to projected climate change impacts requires detailed knowledge of the surrounding ecosystem. To assure accurate assessment evaluation of sensitivity and impact, communities should involve biologists, conservation entities, and/or land managers as part of the climate adaptation team. This assessment can bolster the evaluation with data from the databases made accessible by the California Department of Fish and Game (http://www.dfg.ca.gov/biogeodata/). The team should assess the following:

- Critical habitats
- Special-status species
- Ecosystem services

### Critical Habitats

Assessment of sensitivity should include inventorying and mapping of critical habitats. The inventory should identify the conditions required for this habitat (temperature, moisture, etc.) that may be affected by climate change. In addition, the assessment should identify threats other than climate change to these habitats and/or species, such as pollution and development planned for the future.

### Special-Status Species

Assessment of sensitivity should include inventorying and mapping of special-status species (threatened species, endangered species, species of concern). The inventory should include the conditions required for all stages of the species' life cycle and how they may be affected by climate change. In addition, the assessment should identify threats other than climate change to these habitats and/or species, such as pollution and development planned for the future.

### Ecosystem Services

The focus of this sector is on ecosystems, habitat, and species. Impacts on these systems may have consequences for residents. Changes in habitat characteristics or species distribution and health will affect several community assets and resources. The potential for these impacts should also be recognized during vulnerability assessment. These points of sensitivity are evaluated in other sectors as well. Affected community assets and resources may include the following:

- Public safety: Altered ecosystems can result in changes such as altered pest populations that can serve as a disease vector. In addition, altered ecosystems may be less able to provide ecosystem services such as protection from flood, extreme erosion, and fire.
- Agriculture, forestry, and fishery productivity: All of these industries rely on ecosystem health for productivity. Communities should be aware that habitat and species impacts may also detrimentally influence productivity.

Recreational resources: Many of the ecosystems that support biodiversity also support recreation for residents and visitors alike. Impacts on these ecosystems will also harm their recreational value, which may result in economic consequences.

## 6.5.3 Potential Impact

Non-climate-related threats to species and associated habitats should be identified, as climate change may amplify their impact. These threats can include existing and planned development, water diversion, and other uses of the habitat areas. The focus of this stage in vulnerability assessment is to determine how much the threats will affect the areas of sensitivity identified above.

Evaluating these species and habitats for potential impact requires assessment by staff or stakeholders with knowledge of the local landscape and resident species. These experts should be included in the climate adaptation team.

### Species Range

Based on current population size and distribution, some species may comfortably persist in the face of climate change. This assessment of impact seeks to identify those species that will struggle.

Plant and animal species have a preferred temperature range and ecological setting. Climate change results in altered seasonal temperature and precipitation patterns. In combination, this can alter the suitability of habitats for species. For example, species already surviving at the upper end of their preferred temperature range are likely to experience more frequent and prolonged thermal stress (CNRA, 2007; CDFG, 2007). These changes not only alter the physical comfort of species, but also may alter the entire habitat type. This is particularly true for confined habitats such as lakes, wetlands, or vernal pools, where the combination of reduced precipitation and increased temperature reduces not only the extent but potentially the existence of these habitats and all species that rely on them, due to the species' inability to slowly shift in location.

Species that experience stress due to climate change may migrate (shift their range) to more suitable conditions. However, migration implies a level of habitat accessibility and species mobility that may not be present. Few species – particularly those endemic to California that are adapted to a specific microclimate – are able to adapt to changes without shifting location. If migration is not possible, species risk extinction (CNRA, 2007; CDFG, 2007). The pressures that may lead a species to seek possible relocation affect all habitat types, including aquatic, marine, and terrestrial.

### Invasive Species

The same changes that threaten endemic species described above also influence the ranges and distribution of invasive species. Non-native species, some of which are better equipped for altered conditions, may outcompete native species (CDFG, 2007). Invasive species, a particularly threatening class of non-native species, have tolerance for a wide range of environmental conditions and are able to reproduce, particularly following a disturbance such as wildfire, more quickly and to a great spatial extent than native species. The threat of invasive species is not confined to any one habitat or ecosystem type (CNRA, 2009).

While the short-term biodiversity (native and non-native) may increase, invasive species result in competition for resources (food and habitat), physical damage to invaded habitat, and other impacts that may lead to a long-term loss of native species diversity. Invasive species can predate native species, introduce or transmit disease, or dramatically alter environmental conditions from physical characteristics to chemical, such as water quality (CDFG, 2007). Invasive species threaten not only natural ecosystems but also many ecosystem services, such as agriculture and navigable waterways (CNRA, 2009).

### Ecosystem Interactions

Ecosystems function through a set of interactions, such as pollinator and plant or predator and prey. Climate change can alter the seasonal patterns in an ecosystem such as the timing of flowering, which can end up out of step with pollinators. Some of these impacts can have consequences for the survival of species (CNRA, 2009; CDFG, 2007).

Species that experience stress due to changes in ecosystem condition, such as temperature, do not all have the same capacity to migrate. As a result, newly established ranges are unlikely to have the same complement of ecosystem members (plants and species). These new combinations of species, that may not all be native, must establish interactions that are difficult to predict. Climate change may further affect species due to changes in ecosystem interactions, but the extent and consequences of these changes are not definitively known (CNRA, 2009).

### Hydrologic Cycle

The challenges discussed above regarding habitat range, invasive species, and ecosystem interactions all apply to aquatic systems as well as terrestrial. Wetlands and other aquatic ecosystems are some of the most biodiverse in California and home of many special-status species. Deceased rainfall and altered timing for snowmelt and storm events may result in reduced water levels in aquatic settings (CNRA, 2009; CDFG, 2007). Aquatic and riparian ecosystems will be detrimentally affected by these changes. This will limit the available habitat for species dependent on the ecosystems. Increased temperature not only changes evaporation rates but also alters water chemistry and vegetative characteristics in aquatic ecosystems, exacerbating the changes already occurring due to altered water availability. These changes to aquatic ecosystems will also affect recreational activities.

The change in water timing and availability will have impacts beyond aquatic species and habitats. Terrestrial species, wild or agricultural, also depend on water. Agricultural crops rely on water that is often diverted from surface water systems (rivers and lakes). The reduction in flow level will affect provision of this ecosystem service.

### Disturbance Regime

Flood, drought, and wildfire are all projected to increase in frequency and severity due to climate change. Each of these impacts is addressed in other sectors with respect to their impact on human systems. The focus in this sector is on the impact on natural systems. Ecosystems typically have a recurring disturbance regime that, over the long term, supports biodiversity. By changing the character of these regimes, climate change may detrimentally affect these ecosystems. Results can range from unusually large physical alteration from erosion, to pest outbreaks, to ecosystem shifts (CNRA, 2009). Each of these changes stresses or eliminates native species.

## 6.5.4 Adaptive Capacity

Adaptive capacity for habitats and species is a product of two factors. First, some species and habitats have a greater ability to adapt to change than others. Second, local management practices can support or detract from the capacity of local ecosystems to support a high level of biodiversity. Questions to consider are listed below (CDFG, 2007; Glick, Stein, and Edelson, 2011; NatureServe, 2012).

### Questions Regarding Characteristics of an Ecosystem

- Is the landscape permeable, allowing ease of movement across and between habitat patches and types?
- What is level of redundancy in the ecosystem, particularly for special-status species?
- Does the conservation and open space element in the general plan protect contiguous tracks of habitat?
- Are there management plans developed for protected open space in the community?
  - Do these plans explicitly protect sensitive species and habitats?
- Has the community established a monitoring program to track changes in species population and ecosystem health?
- Is there a land conservancy or similar organization that works to protect vulnerable habitat?
- Has the community established an impact fee to fund land management and/or acquisition?
  - Is there a plan guiding this investment?

### Questions Regarding Characteristics of Species

- Is the species able to modify behavior of physiology with shifting conditions?
- Is the species able to move over large distances (e.g., through seed dispersal mechanisms)?
- Does the species have robust genetic diversity (related to population size)?

## 6.5.5 Onset and Risk

Many of the factors that influence a changed seasonal pattern are labeled as moderately certain (see Table 1). Wildfire, drought, and extreme rainfall also are viewed as moderately certain. The impact of climate change on biodiversity is not due to any single factor, but rather the collective outcome of several impacts. Change in the seasonal distribution of precipitation and temperature will affect biodiversity. The fact that these impacts cannot be precisely projected on small spatial scales does not imply that change is not occurring. It simply places a burden on a community to track the behavior and health of local ecosystems.

**Additional Resources**

- California Department of Fish and Game. 2007. California Wildlife: Conservation Challenges - California's Wildlife Action Plan. Sacramento. Retrieved from www.dfg.ca.gov/habitats/wdp/. The Wildlife Action Plan provides an excellent explanation of climate change impacts on wildlife and the specific impacts likely to be experienced in various regions in the state. In addition, strategies for addressing these impacts are explored.
- Glick, P., B.A. Stein, and N.A. Edelson (eds.). 2011. Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment. National Wildlife Federation, Washington D.C. Retrieved from http://www.nwf.org/vulnerabilityguide This is a clear guide to vulnerability assessment focused on biodiversity on habitat.
- NatureServe. 2012. NatureServe Climate Change Vulnerability Index. Retrieved from http://www.natureserve.org/prodServices/climatechange/ccvi.jsp This is a step-by-step vulnerability assessment for plant and animal species. You can download an interactive Excel spreadsheet, guidance, and a training session.

## 6.6 Agriculture

California produces well over 250 agricultural products, making it both the most diverse and profitable agricultural economy in the United States (Cavagnaro, Jackson, and Scow, 2006). More than 50 percent of these products are fruits, vegetables, and tree nuts. Dairy products make up the largest portion of the state's agricultural economy (Cavagnaro, Jackson, and Scow, 2006). Climate change impacts on California's agricultural sector will have far-reaching impacts, from altering local economic conditions to affecting the food supply for the state and – due to the scale of the market – the nation.

Climate change poses threats that may negatively influence crop and livestock productivity. These threats include extreme events (e.g., flooding, fire) that result in large losses experienced over shorter time durations, as well as more subtle impacts such as changed annual temperature, precipitation patterns, and water scarcity (e.g. reduced precipitation or irrigation availability) that influence growing seasons, weed and pest populations, or livestock health. These impacts also have the potential to result in a range of associated consequences such as reduced air quality and farm worker safety.

The California Adaptation Strategy identifies the following threats to agriculture in California (CNRA, 2009, p. 96):

- Loss of water supply and reliability
- Loss of food security as water supply diminishes and/or is less reliable
- Loss of irrigated lands, crop production, and food security
- Lack of water for agriculture and livestock
- Drier conditions that may affect agricultural crop yields
- Increased fire risk to rangeland
- Dry steep terrain - increased soil erosion and sedimentation from agricultural lands
- Changes in pests, diseases, and invasive species
- Changes in ozone and air quality - likely adverse affects on crop production

The severity of impacts depends on a variety of factors, from the type of agricultural operation to water distribution to geographic location. This assessment briefly reviews some of the impacts and issues faced by the agriculture industry in California, but the specifics of determining community vulnerability are left to local community representatives who are most familiar with the specific geographic characteristics, agricultural practices, water availability, and local conditions.

Agriculture activity primarily occurs on private property. Local and regional governments have limited ability to directly influence agricultural operations. Governmental entities must focus on those ways in which climate change impacts affect community assets, functions, and populations. The two most common ways in which this may occur are the following:

- Business continuity: Communities in which agriculture comprises a large portion of the economic base must assess not only direct climate threats to agricultural operations, but also the secondary consequences for other businesses in the community. These consequences can include direct and indirect employment and overall community economic security.
- Public health: Increased temperature, including heat waves, and reduced rainfall can have health consequences for local residents, particularly the agricultural workforce. Changes in weed and pest distributions can result in altered pathways for infection.

Agriculture can be threatened by climate change impacts such as water scarcity, flooding, and wildfire. Each of these threats is summarized in the discussion of other sectors. The considerations identified in these sections also apply to agricultural areas.

## 6.6.1 Exposure

There are two primary climate change impacts that will affect agriculture: temperature changes and precipitation changes. Several secondary impacts, such as changed seasonal weather patterns, heat waves, intense rainstorms, drought, and wildfire, are also of concern. The Cal-Adapt maps show expected changes in temperature, precipitation, and wildfire but do not show the areas affected by the other impacts. Nevertheless, communities that experience increasing temperatures and/or decreasing precipitation are likely to have increased susceptibility to drought – a key concern in agricultural communities.

Since sensitivity to temperature and precipitation is crop-dependent, communities will need to identify their current crop mix in order to decide whether crops would be affected by the anticipated climate exposures or which climate exposures will be of most interest.

An important exposure consideration will be precipitation in basins that supply water for the community either through surface water or groundwater. If the agriculture sector is supplied with water from sources outside of the community, projected changes in precipitation or snowpack in those source areas should be examined.

## 6.6.2 Sensitivity

There are several resources and assets that should be assessed when considering the impacts of climate change on agriculture. Members of the agricultural community should be members of the climate adaptation team to aid in this evaluation. The examination of climate impact on agriculture is similar to the type of assessment conducted for biodiversity. A community should consider the following issues in developing the sensitivity analysis:

- Agricultural product mix and needed conditions
- Water supply
- Socio-economic assets

### Agricultural Product Mix and Needed Conditions

Assessment of sensitivity should include the inventorying of agricultural products grown or processed within the community. This inventory should include a description of the temperature and precipitation regimes that are needed to support optimal productivity of the agricultural product. Some products may have very narrow growing conditions that could be affected by small changes in temperature or precipitation. Others may be tolerant of changing conditions such as drought and thus more resistant to the effects of climate change.

### Water Supply

Assessment of sensitivity should include an evaluation of the reliability of the water supply given changing precipitation regimes. The assessment of reliability should consider both physical and legal issues.

### Socio-Economic Assets

Assessment of sensitivity should include a study of the local social and economic assets that depend on agricultural productivity. Because jurisdictions have little authority over agricultural operations, the points of sensitivity come where a community interacts with agricultural operations. These can include the following:

- Economic continuity: Businesses in an agricultural community are often reliant on the agricultural industry even if they do not directly participate. Changes in the economic viability of agricultural operations can affect the commercial and business sector of a whole community.
- Employment base: One way in which economic continuity can be affected is in employment base. Those affected can include agricultural workers and those employed at dependent businesses.
- Public health: Climate change may alter the type, severity, and frequency of human health ailments that a community must address.

## 6.6.3 Potential Impact

The extent to which a community's points of sensitivity (identified above) will be affected will depend on local environmental conditions and the extent to which the local economy and employment base rely on the agricultural sector. This evaluation should include the following considerations:

- Will climate change push agricultural operations beyond the range of optimal temperature and water conditions?
- How sensitive are the agricultural operations to climate change impacts (e.g., will productivity decrease a little or a lot)?
- How long will the changes take to occur?
- How likely is a reduction in water supply due to climate change?
- How susceptible are agricultural operations to altered pest and weed distribution?
- What proportion of the community employment base is reliant on agriculture?
- Do local health services have the capacity to meet the challenges of worsening heat and air quality impacts on agricultural workers?

## 6.6.4 Adaptive Capacity

The capacity for adaptation is most often related to the degree to which agricultural operations can accommodate changing conditions. This ability can vary widely depending on the type of operation being considered. In addition to the adaptability of community agricultural practices, government policy can support agricultural operations stressed by climate change. Adaptive capacity can be evaluated by considering the following:

- How easy or difficult is it to change to a more tolerant agricultural operation (change in crop type, change in grazing practice, etc.)?
- Is the product able to be changed (e.g., through a shift in annual crop type)?
- Is the operation able to be altered to better accommodate climate change (e.g., through a shift to drip irrigation, shade provision for dairy operations, etc.)?
- Is there a robust drought plan in place?
- Is there a regional management plan for weed and/or pest distribution?

- Do the local health services have plans in place for accommodating heat or respiratory ailments experienced by farm workers? Do they have additional capacity if conditions worsen?
- Are there local entities that support agricultural adaptation activities (e.g., resource conservation districts, cooperative extension, land trusts, etc.)?
- Is there a funding mechanism (e.g., impact fee, carbon offset or capture, etc.) to fund operational shifts?

### 6.6.5 Risk and Onset

The IPCC labels temperature change as an impact with high certainty, whereas precipitation change is considered to have medium certainty of occurring (table 2). The interaction of these two factors yields changes in seasonal weather patterns, which are also labeled as having a medium level of certainty (table 2). Further complicating the challenge of projecting climate impacts is the degree to which local operations influence the level of impact that will be experienced. Climate change will affect agricultural operations, but greater specificity with regard to the degree of impact is only possible through close collaboration with the agricultural community in a given setting.

- Waste (sewer, storm, and solid waste)
- Electricity generation and distribution
- Gas production, storage, and distribution
- Communications

## 6.7 Transportation and Energy Infrastructure

Infrastructure provides the resources and services critical to community function. Roads, rail, water (pipes, canals, and dams), waste (sewer, storm, and solid waste), electricity, gas, and communication systems are all necessary for human survival and prosperity. Climate change increases the likelihood of both delays and failures of infrastructure. Temporary delays/outages will result in inconveniences and economic losses, while larger failures of systems will result in, at times, disastrous economic and social effects.

Assessing the vulnerability and developing strategies to address threats to infrastructure is complicated due to the connectivity or system-type design. Most infrastructure is arranged as a series system similar to a chain, which can mean that when one link fails the entire chain fails. Infrastructure is designed to meet the expected load; however, every blackout or traffic detour is an example of a system exceeding its designed limit. Climate change has the potential to exacerbate system overloads and result in more frequent blackouts, detours, slowdowns, and/or service reductions.

In order to adapt to climate change, it is essential to identify the points of weakness in a system and estimate how climate change will increase the load in a system. Adapting to change is complicated by the fact that many systems are already vulnerable. The American Society of Civil Engineers (ASCE) has evaluated the state's current infrastructure as poor and failing in nearly every infrastructure category (ASCE, 2006). Climate change and its effects will strain current infrastructure, creating the potential for increased delays and outages and also a higher likelihood of disastrous failures.

Because of the distributed nature of infrastructure, local jurisdictions will need to assess what is within their control and what is not and adapt accordingly. The following categories of infrastructure are covered in this section:

- Transportation (road, rail, air, water)
- Water distribution
- Waste (sewer, storm, and solid waste)
- Electricity generation and distribution
- Gas production, storage, and distribution
- Communications

## 6.7.1 Exposure

Nearly all of the areas of climate change impact will affect the infrastructure sector. Of primary concern will be impacts on infrastructure in the coastal zone due to sea level rise. In addition, increased storm intensity, temperature, and wildfire may affect infrastructure. Communities will need to consider the location of their infrastructure in order to determine which areas of exposure such as the following are most relevant:

- Sea level rise (and related issues of coastal erosion, extreme high tide, coastal flooding): consider if the community has infrastructure within the coastal zone
- Snow season and depth change: consider if the community has infrastructure in snowy areas
- Salt water intrusion: consider if the community depends on groundwater resources within the coastal zone
- Intense rainstorms and landslide: consider if the community has infrastructure in or near areas subject to flooding or landslide
- Wildfire: consider if the community has infrastructure in or near areas subject to wildfire

## 6.7.2 Sensitivity

Because infrastructure is critical to society's basic functions, even small failures can result in large consequences. Additionally, it is important to consider how one failure can cascade into another, turning a small delay into a catastrophic system failure. The power outage that left San Diego County without power in September 2011 resulted in traffic jams, canceled flights, closed schools, and $100 million in regional economic losses. The outage was also directly responsible for causing city sewer pumps to fail, resulting in a combined two million gallons of sewage spilling at two sites (CBS, 2011).

Mapping local infrastructure and large distribution infrastructure leading into and out of a jurisdiction to the source and overlaying current and projected hazard maps will help in understanding the risk and highlighting the areas where adaptation is needed (see Figure 14). Visualizing the vulnerability of each type of infrastructure to each individual hazard and understanding the consequences of delays or failures will help to set adaptation priorities. The climate adaptation team representatives from utilities, transportation, and engineering departments can aid in identifying infrastructure sensitive to identified exposure.

The community functions and assets most likely to be affected by climate-related disruption of infrastructure systems include the following:

- Public safety
- Public health
- Business continuity
- Emergency services
- Access (home, work, and supply chains)

Most infrastructure outages will occur during extreme conditions when the public is most reliant on access to resources and information. The disruptions of these services will limit the ability of individuals to help themselves as well as the ability of emergency services to respond to needs.

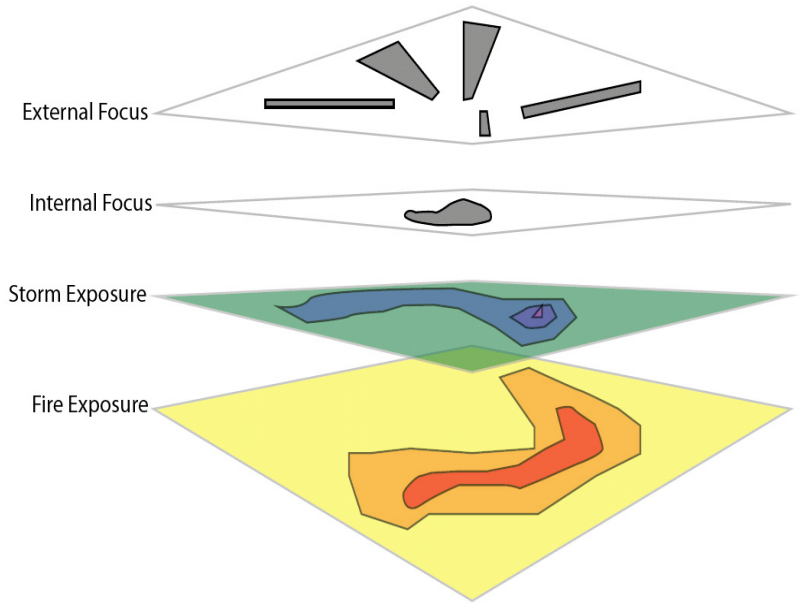



Figure 8. Illustration of layering of regional and local assets along with exposure to identify infrastructure connections and sensitivity.

## 6.7.3 Potential Impact

To understand the risk to infrastructure for a given jurisdiction, it is critical to view the problem both internally (locally) and externally (regionally) (see Figures 14 and 15). It is important that a jurisdiction determine the location of infrastructure, its current condition, and its susceptibility to climate impacts. For infrastructure that enters from outside the jurisdiction, it is critical for the jurisdiction to trace the infrastructure back to its source and determine the risks in the infrastructure's path.

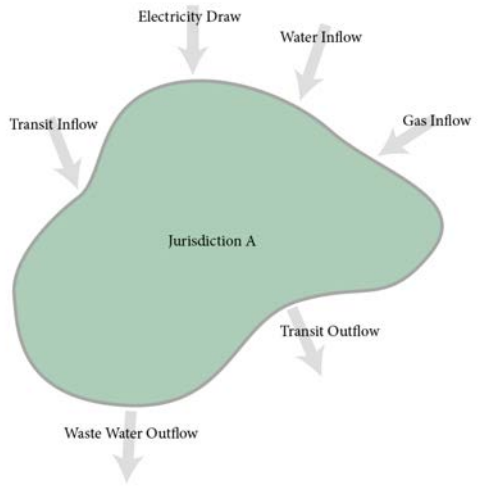



Figure 9. Conceptual map of how a jurisdiction can identify impacts on infrastructure on a regional scale.

## Sea Level Rise

Sea level rise is expected to affect:

- Transportation systems (road, rail, ports) through erosion and inundation;
- Wastewater and stormwater systems that are designed for current mean sea level outfall levels; and
- Electricity generation infrastructure built with respect to current mean sea level and reliant on the sea level for cooling.

Sea level rise interacts with infrastructure systems by creating two critical problems: inland flooding and erosion. With increased water level and storm intensity, inland flooding and erosion rates will increase. Coastal transportation corridors (both road and rail) are at risk of service interruption due to inundation and erosion. These coastal corridors are critical for both local commuting as well as a portion of shipping. Local coastal infrastructure distribution systems (water, wastewater, electric lines) may be affected by inundation or erosion.

Wastewater and storm drain systems are not only subject to erosion caused by sea level rise and storm intensity. In addition to those risks, the elevation difference between the ocean and draining systems will be different in the future, affecting the outfall elevation for storm and sewer systems in coastal cities.
A number of power and wastewater facilities are built near water for outflow and cooling needs. A number of these facilities are in either sea level inundation zones or are at serious risk of erosion.
There are two data sources that can be used to assess local exposure to sea level rise impacts: (1) Cal-Adapt, which maps inundation areas for a 55-inch increase in sea level; and (2) FEMA flood maps that include sea level rise in estimating the floodplains for coastal waterways.

## Storm Intensity

An increase in precipitation and storm intensity is expected to affect:

- Transportation, through increased landslides caused by precipitation;
- Water infrastructure, through higher loading due to larger peaks in the runoff; and

- Electricity infrastructure, though wind or precipitation related outages.

The cycle of landslides closely follows the rainfall intensity in the winter months. Repeated periods of high-intensity rainfall often result in landslides throughout the state, resulting in, among other things, closures of roads, rail lines, and other transportation systems. The roughly decadal recurrence of the La Conchita landslide is caused by winter storms that in the last failure completely closed Highway 101 and the parallel rail corridor for a week.

Flooding and landslide hazards can be mapped using MyPlan (http://myplan.calema.ca.gov). Some soils are more prone to failures than others; organizations like the United States Geological Survey (USGS) and California Geological Survey (CGS) have created detailed maps of the soil types. Additionally, for some jurisdictions, CGS has detailed maps marking at-risk landslide zones.

Water infrastructure, such as dams and levees, has been designed based on historical records of peak runoff. An increase in the precipitation intensity can result in higher loading of these systems than they were designed for, threatening flood control and water distribution.

Increases in intensity of storms will result in an increase in failures that are common in current storms. Common infrastructure outages caused by precipitation and wind include downed power and communication lines. These failures are caused directly by the wind, or indirectly by debris and vegetation (PG&E, 2012).

The quantity of precipitation, snow, and ice will also cause an increase in delays and closures. Mountain passes will see greater quantities of snow in single storm events. Areas that typically do not see snow and ice will have to deal with ice- and snow-covered roads, causing primary delays (slowed speed) as well as blockages (increased accidents). Rain and snow can cause immediate and delayed flooding that, when interacting directly with infrastructure, will result in failures of systems.

## Temperature

Changes in temperature can be expected to affect:

- Communication infrastructure. Changes in temperature and other climate conditions may damage communication infrastructure, which may in turn cause fires.
- ransportation infrastructure. Changes in temperature may damage materials used in roads and other transportation infrastructure.

Changes in temperature will influence fire throughout the state. Fire can have a large impact on infrastructure. Fires that intersect with infrastructure will cause blockages as well as the potential to cause complete destruction of a section of infrastructure.

All infrastructure has the potential to be damaged by fires, but grid communication and gas lines are the most susceptible to failures. On December 1, 2011, Santa Ana winds disrupted power to 114,000 customers in Los Angeles County. The power disruption caused transportation closures and made responding to the related emergencies difficult.

Cal-Adapt (http://cal-adapt.org/) has temperature projections as well as changed moisture temperature regime projections that will help identify expected changes. The Section 6.6, Forest and Rangeland, has additional detail about the impact of climate change on wildfire.

Many fires are caused by infrastructure. High temperatures can cause electricity lines to sag, leading to contact and sparking. High winds can cause downed power lines and sparks, producing a fire adjacent to the infrastructure system. Additionally, autos can start fires on the perimeter of roads, again resulting in a fire adjacent to infrastructure. This feedback loop is often difficult to identify and will require tackling current interactions as well as adapting to an increased frequency with climate change.

The increase in average temperature will also have a cumulative impact on the material properties of infrastructure systems. Individual days of extreme temperatures can also produce failures. Typical construction materials degrade in extreme heat, cold, and moisture. An increase in the intensity of these elements will result in more rapid degradation of an already aged infrastructure. Future concrete infrastructure will need more concrete cover to protect the core of the structure (CSIRO, 2010). Higher levels of carbon dioxide will increase the speed and penetration of concrete carbonation, which deteriorates the strength of concrete (Yoon, 2007).

### 6.7.4 Adaptive Capacity

Many of the threats to infrastructure are already accounted for in the planning and design of the systems. Assessing the adaptive capacity evaluates the degree to which these systems are able to withstand the conditions projected in the future as a result of climate change. First and foremost, the current management plans for infrastructure systems, as well as future plans and funding allocations, must be evaluated. Questions to consider include the following:

- To what extent have redundancies been built in to community infrastructure systems?
  - Water/Wastewater
  - Energy
  - Transportation
  - Communication
- What emergency procedures are currently in place for infrastructure systems?
- What measures are contained in the local hazard mitigation plan (communication, evacuation, emergency services, etc.)?
- Has there been funding allocated for these systems?

Addressing each of the community functions and assets most likely to be affected by climate change is important. The following are some questions to consider:

#### Public Safety

- Are there redundant means of communication for community members during a hazard event?
- Are evacuation notices communicated in all languages spoken in local households?

#### Public Health

- Are there specific plans in place in the event of a loss of wastewater conveyance and treatment services?

#### Business Continuity

- What businesses are vital to day-to-day operations (e.g., grocery stores, gas stations, etc.) and is there redundancy so that food, gas, and other essentials can be maintained?

#### Emergency Services

- Have evacuation routes been assessed for climate vulnerability?

### Access (home, work, and supply chains)

- Are there neighborhoods with one or more current access points vulnerable to climate change impacts?

## 6.7.5 Onset and Risk

The IPCC considers sea level rise to be of high probability, therefore coastal communities should consider the potential impacts of sea level rise to be of higher priority for adaptive planning than other potential effects of climate change. The current rate of sea level rise over the last decade is about 0.12 inch per year; thus, the current onset of sea level rise is relatively slow. The rate is expected to increase closer to the 2100 forecast year.

The IPCC considers temperature increase to be of high probability; therefore, communities should consider the potential impacts of temperature rise to be of high priority for adaptive planning. Cal-Adapt shows expected temperature until 2090. These projections can be used to determine onset and rate of change over time.

The IPCC has not established probabilities for change in storm intensity risk. The IPCC has established changes in precipitation as medium probability and changes in temperature as high probability. Therefore, using the more conservative of the two, it is recommended that changes in storm intensity be considered to be of medium probability.

# 7.0 Climate Impact Regions

The APG is organized into a series of climate impact regions (see Figure 10). The choice to designate regions is due to the statewide diversity in biophysical setting, climate, and jurisdiction characteristics. While conditions may be diverse within each region, the range of conditions will be narrower than at the statewide level. Designating regions thus allows for greater depth and more detailed guidance to be presented.

Regions were designated based on county boundaries in combination with projected climate impacts, existing environmental setting, socioeconomic factors, and regional designations. The choice to use counties, i.e., political boundaries, was based on a commitment to make the APG as useful as possible for local governments. The counties were clustered into regions based on the following factors:

- **Projected climate change impacts** were evaluated using Cal-Adapt. Cal-Adapt climate impact projections for precipitation, temperature, snowpack, and wildfire risk were used to identify counties that share a similar group of projected impacts.
- **Existing regional designations** were evaluated because there are some climate-related impacts best addressed at a regional scale. Counties that share a regional designation (e.g., air district, Regional Water Quality Control Board) are more likely to have already established relationships with neighboring jurisdictions that are necessary for regional strategy development and implementation. The regional designations examined include Regional Water Quality Control Boards, air basins and air districts, California Emergency Management Agency Regions, and Metropolitan Planning Organizations. Figures 11 through 15 overlay the impact regions with these regional designations.
- **Habitat** was assessed based on bioregion, habitat, and land cover maps developed by the California Department of Forestry and Fire Protection, Fire and Resource Assessment Program (FRAP). These data were included when determining the regions because the potential consequences of a change in climate (e.g., temperature and precipitation) vary based on the preexisting biophysical setting. Figure 12 displays the climate impact regions in comparison to bioregion.
- **Socioeconomic characteristics**, including the location of major population centers and economic base, were considered. These characteristics were particularly important for counties that have more than one area with distinct suites of projected climate impacts. For example, a county that shares some characteristics with the Northern Sierra and others with the Northern Central Valley was evaluated based on which setting supported the local economy to a greater degree and/or was home to a larger portion of residents.

Based on the factors described above, 11 regions were identified (see Figure 10) Some of the regions were based on specific factors particularly relevant to the region. For example, the Central Valley was split into north and south based on hydrologic boundaries; this results in the Northern Central Valley region containing all counties draining to the Sacramento-San Joaquin Delta. The Sierra Nevada area was split based on ecosystem differences as well as variation in projected climate impacts. The Bay-Delta is the only region that shares all its counties with other regions. The designation of the Bay-Delta as a region recognizes that this area is distinct due to its elevation profile and flood vulnerability. Additional detail about the characteristics of each region can be found in Part 2: Regions.

The regions are defined as follows:

| | |
|---|---|
| **North:** | Lassen, Modoc, Shasta, Siskiyou, and Trinity |
| **North Coast:** | Del Norte, Humboldt, Lake, and Mendocino |
| **Bay Area:** | Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma |
| **Central Coast:** | Monterey, San Benito, San Luis Obispo, Santa Barbara, and Santa Cruz |
| **Northern Central Valley:** | Butte, Colusa, Glenn, Madera, Merced, Sacramento, San Joaquin, Stanislaus, Sutter, Tehama, Yolo, and Yuba counties |
| **Bay-Delta** | Contra Costa, Sacramento, San Joaquin, and Solano, Yolo counties |
| **Southern Central Valley:** | Fresno, Kern, Kings, and Tulare counties |
| **North Sierra:** | Amador, Calaveras, El Dorado, Mariposa, Nevada, Placer, Plumas, Sierra, and Tuolumne counties |
| **Southeast Sierra:** | Alpine, Inyo, and Mono counties |
| **South Coast:** | Los Angeles, Orange, San Diego, and Ventura counties |
| **Desert:** | Imperial, Riverside, and San Bernardino counties |

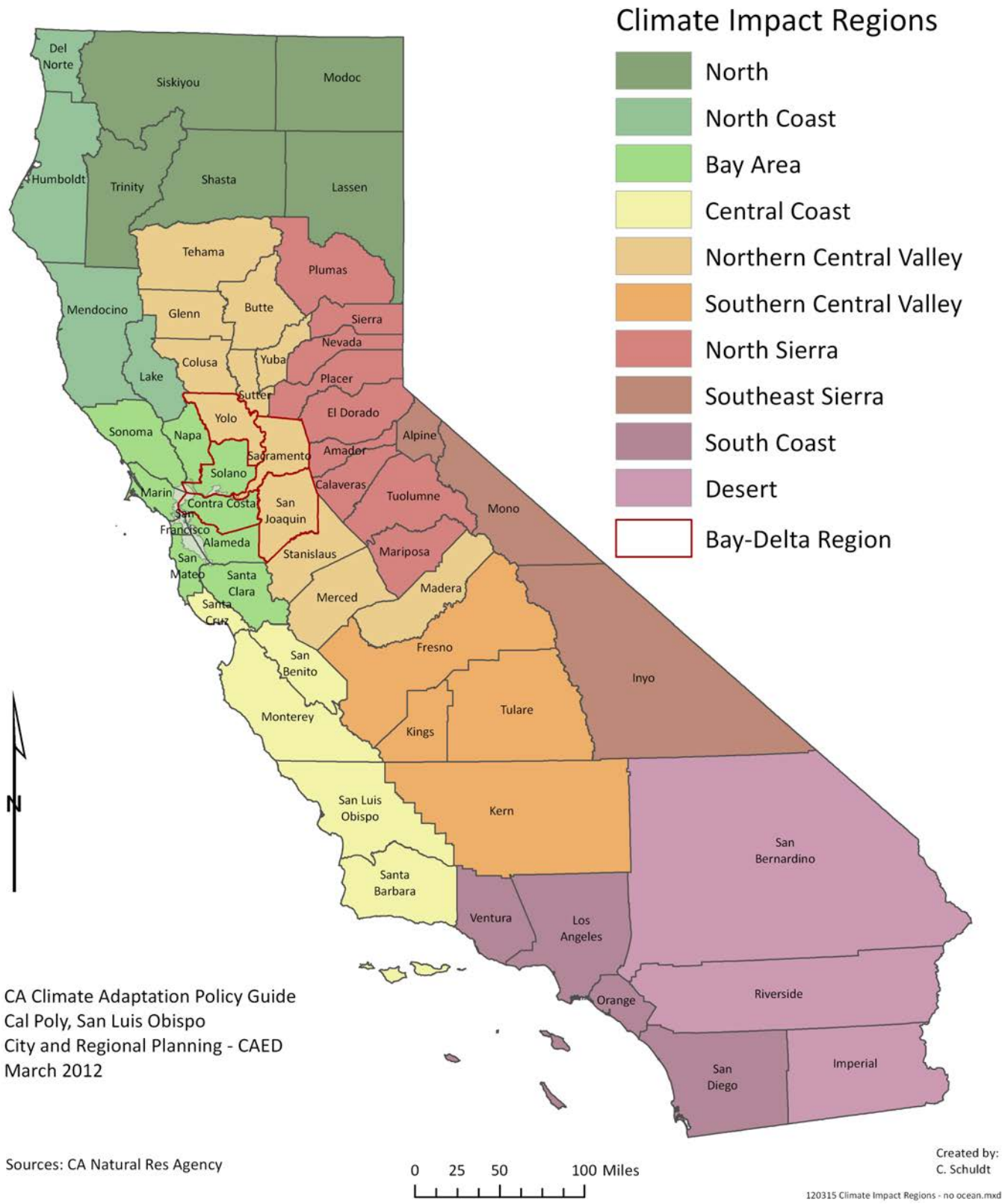



**Figure 6. Adaptation Policy Guide: Climate Impact Regions**

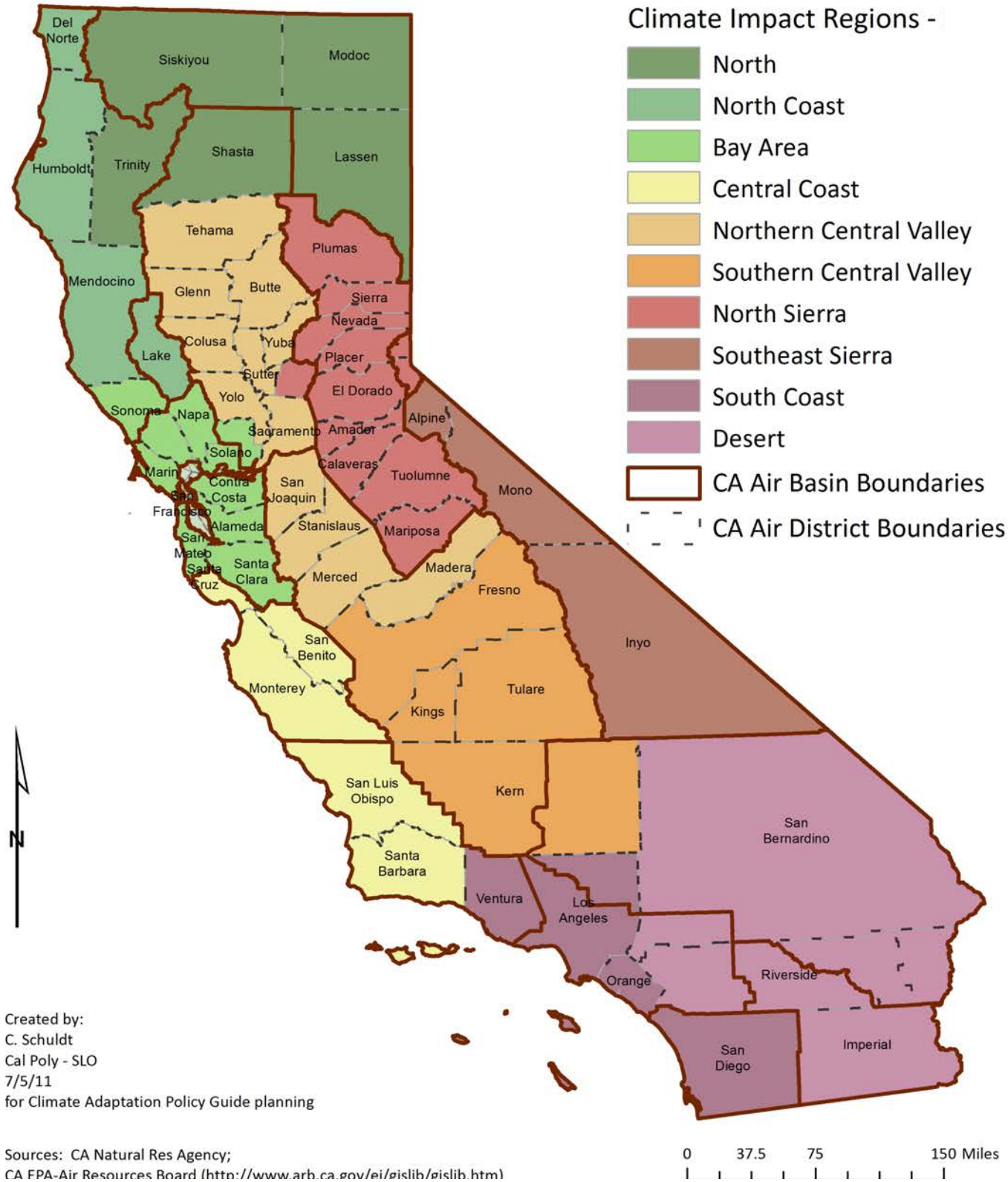



**Figure 7. California Air Resources Board Air Basin and Air District boundaries in comparison to the Adaptation Policy Guide climate impact regions.**

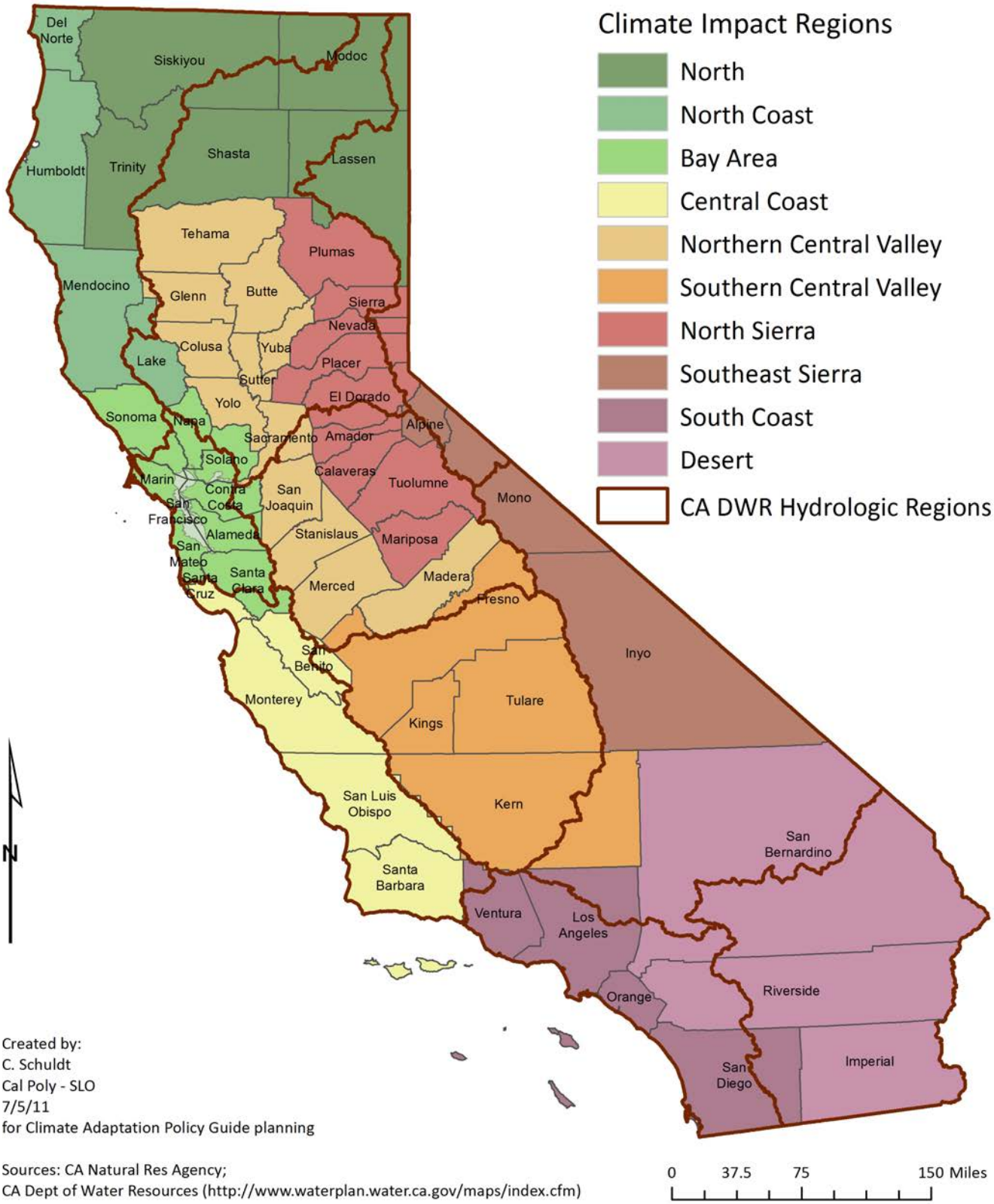



**Figure 8. California Department of Water Resources Hydrologic Regions in comparison to the Adaptation Policy Guide climate impact regions.**

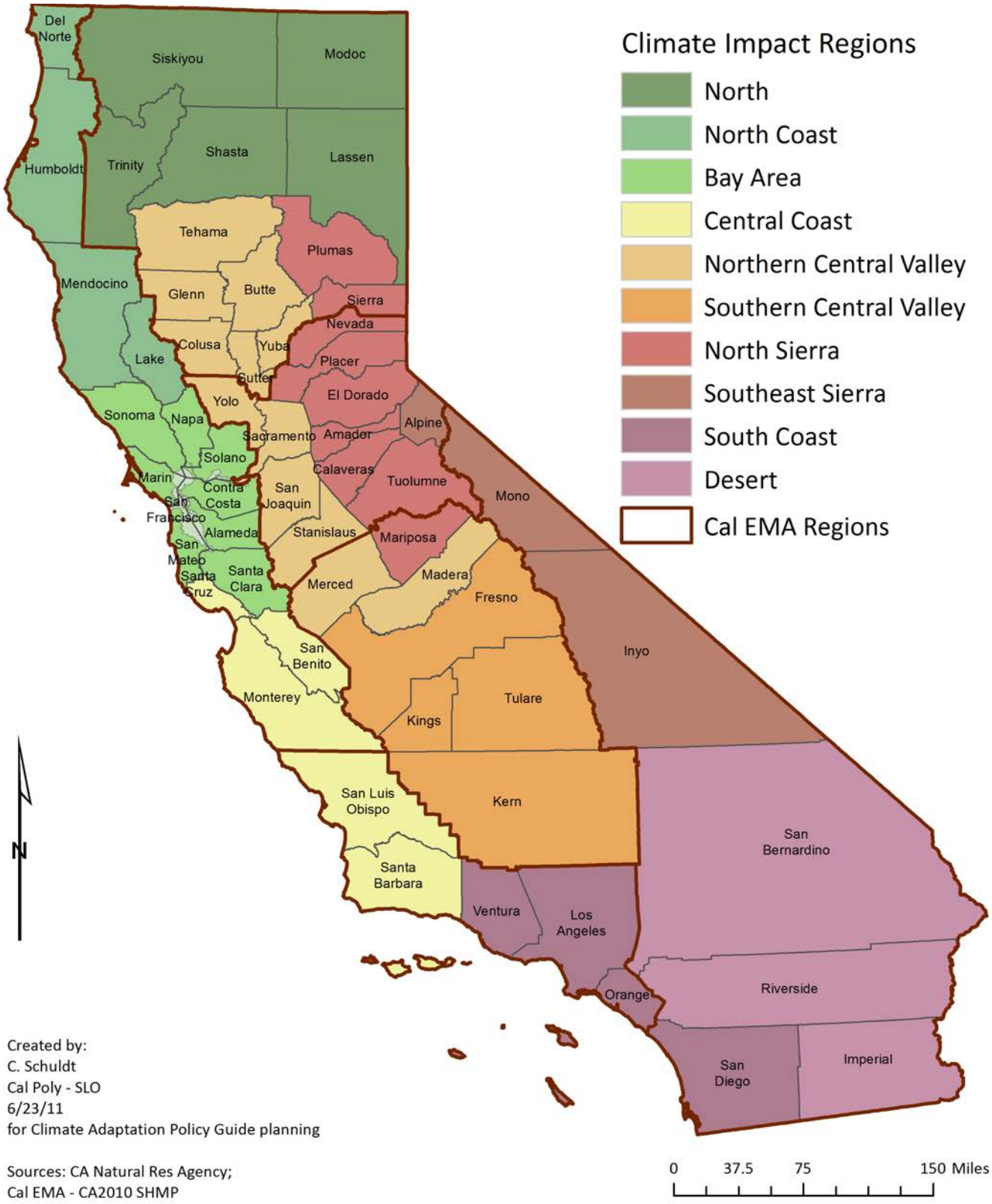



**Figure 9. California Emergency Management Agency regions in comparison to the Adaptation Policy Guide climate impact regions.**

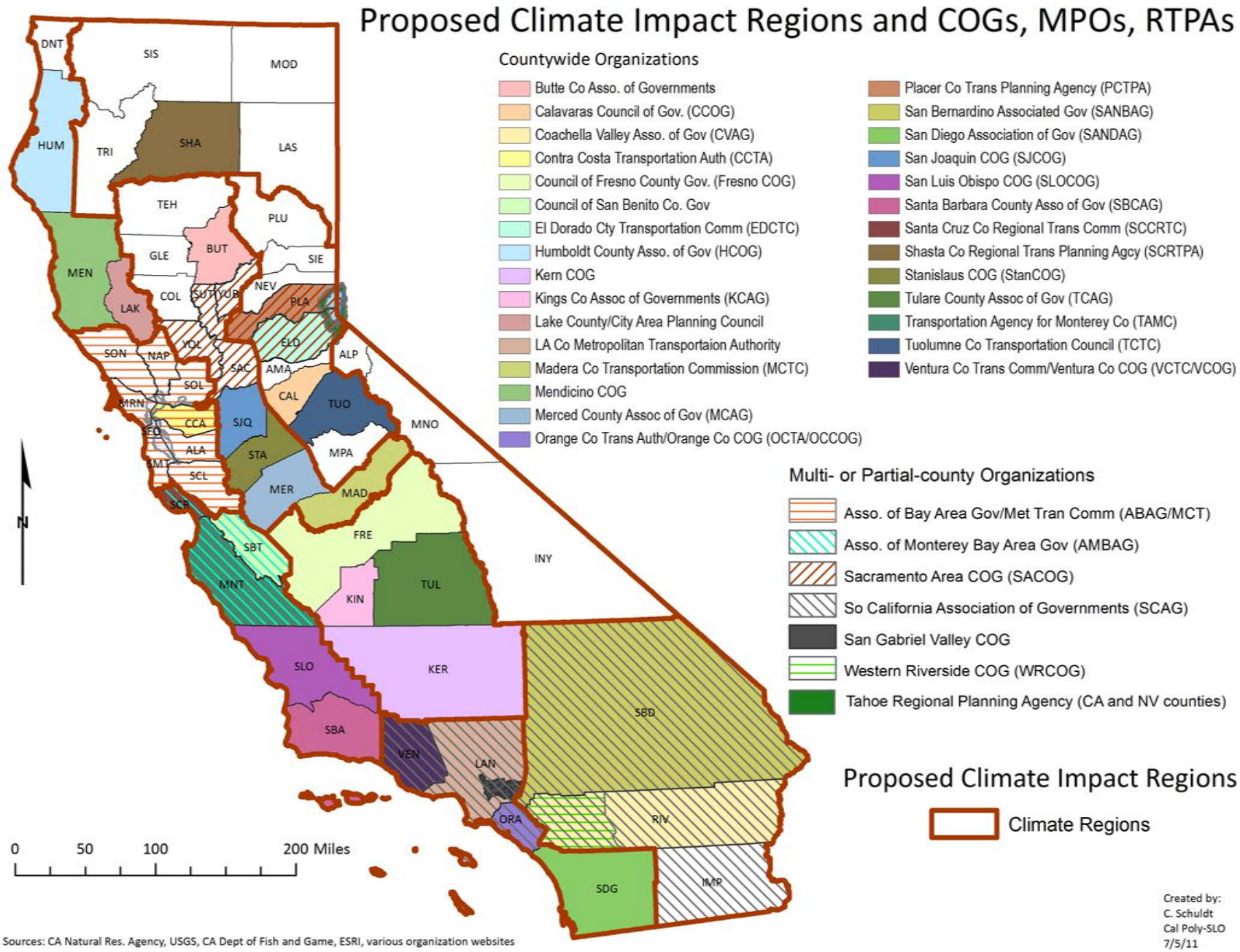



**Figure 10. Adaptation Policy Guide climate impact regions in comparison to the boundaries of California Councils of Government (COGs), Municipal Planning Organizations (MPOs), and Regional Transportation Planning**

**Figure 11. California state bioregions in comparison to the Adaptation Policy Guide climate impact regions.**

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# ADAPTATION POLICY GUIDE
# PART 2: REGIONS

Images: California Department of Water Resources

# 1.0 Regional Adaptation Considerations

### North Coast
- Less snowpack
- Increased wildfires
- Sea level rise and inland flooding
- Threats to sensitive species (e.g., coho salmon)
- Reduced agricultural productivity (e.g., forestry, wine grape, nursery products, dairy)
- Public health and safety

### North
- Increased wildfire
- Reduced snowpack
- Ecosystem shifts and non-native species
- Flooding
- Economic impact (timber, tourism, grazing)
- Reduced public health due to air pollution (especially for elderly)

### Bay Area
- Sea level rise – coastal inundation and erosion
- Public health – heat and air quality
- Reduced agricultural productivity (e.g., wine grapes)
- Public safety
- Inland flooding

### Northern Central Valley
- Nighttime temperature increase
- Flooding – storm flows, snowmelt
- Reduced agricultural productivity (e.g., nut trees, dairy)
- Reduced water supply
- Wildfire in the Sierra foothills
- Public health and heat

### Bay-Delta
- Reduced water supply
- Reduced agricultural productivity
- Flooding
- Public safety

### Southern Central Valley
- Reduced water supply
- Reduced agricultural productivity
- Flooding
- Decrease in tourism – Sierra Nevada foothills
- Decreased public health
- Wildfire risk in the Sierra Nevada foothills
- Public health – heat and air quality

### Central Coast
- Reduced agricultural productivity
- Sea level rise – coastal flooding and infrastructure damage
- Biodiversity
- Public health threats

### North Sierra
- Increased temperature
- Decreased precipitation
- Reduced snowpack
- Reduced tourism
- Ecosystem change
- Sensitive species stress
- Increased wildfire

### Southeast Sierra
- Increased temperatures
- Reduced precipitation
- Economic impacts – tourism decline
- Substantially reduced snowpack
- Flooding

### South Coast
- Sea level rise
- Economic impacts – tourism, water supply
- Reduced Water supply
- Wildfire risk
- Public health – heat and air quality

### Desert
- Reduced water supply
- Diminished snowpack
- Public health and social vulnerability
- Stress on special-status species

# 2.0 Introduction

Part 2 of the APG reviews the climate adaptation regions. It is intended to complement the vulnerability assessment, policy development process, and sector sections found in Part 1 of the APG. Part 2 reviews each region in the state, providing detail or specificity above and beyond that presented in the sector sections. For each region, Part 2 provides specific information likely to aid in evaluation of vulnerability and formulation of adaptation strategies. This information includes the following:

- **Cal-Adapt Projections.** Cal-Adapt projections for the region are provided, along with an indication of the model and emissions scenario on which these projections are based. The table provided for each region is intended as a summary of the types of changes projected for the region. Local jurisdictions also should use Cal-Adapt to generate more projections specific to their locations.
- **Water Sources.** The primary sources of water for the region are identified to allow for general identification of potential vulnerability associated with supply. Because each jurisdiction acquires rights to its community water supply, individual jurisdictions should assess their water supply. This evaluation will have much greater specificity, allowing for community-based vulnerability assessment.
- **Biophysical Characteristics.** A short summary of major regional features is provided. In regions with ecosystems or special-status species that are particularly vulnerable to climate change, a more detailed discussion of these issues is provided following the listing of basic data.
- **Regional Entities**. A list of air districts, regional organizations, and tribal lands in the region is provided. Some climate change impacts are best addressed on regional scales. Regional organizations, and the local jurisdictions associated with them, may represent potential collaboration partners for devising regional adaptation strategies, from infrastructure continuity to migration corridors for sensitive species.
- **Major Infrastructure and Selected Regional Resources**. A brief summary of major infrastructure and other regional facilities is provided. Infrastructure, including transportation, electricity, water, wastewater, and natural gas, involves linear systems critical for the provision of services. Major infrastructure can link communities in a region and facilitate processes on a state and national level. Other resources addressed include wastewater treatment plants, power plants, and hospitals. Also included are state and federal parks that may be affected by climate change but also serve as a resource in devising adaptation strategies, particularly for sensitive species.
- **Selected Demographic Data.** Selected employment and population data for the region are provided. Certain populations are more likely to be affected by climate change than others. The table provided for each region lists populations under five years old and populations at or below the poverty level. Local jurisdictions should complement these data with locally specific information, such as demographic data (poverty, percent elderly, percent children) that are available on a county basis. Local jurisdictions will need to evaluate these data on a scale appropriate to their jurisdiction.
- **Adaptation Policy Considerations.** The discussion of each region concludes with a summary of issues to consider in developing climate adaptation policy for jurisdictions within the region.

# 3.0 North Coast Region

***Counties:*** Del Norte, Humboldt, Lake, Mendocino

***Five Largest Cities (CDOF, 2011)***: Eureka (27,283); Arcata (17,318); Ukiah (16,109); Clearlake (15,289); Fortuna (11,977)

| Total 2010 Population | |
|---|---|
| **North Coast Region** | **315,739** |
| Del Norte | 28,610 |
| Humboldt | 134,623 |
| Lake | 64,665 |
| Mendocino | 87,841 |

[U.S. Census Bureau, 2010]

The North Coast is a lightly populated, sparsely settled region, with only one city over 20,000 people (Eureka). It represents the northern coast of the state. It is home to the largest timber-producing county in the state (Humboldt) and two wine grape-growing counties (Mendocino and Lake). In addition, the North Coast is home to sandy beaches and several estuaries that support rich biodiversity. Due to varied terrain, it is also home to several microclimates and distinct ecosystems.

Potential climate change impacts to be considered by North Coast communities include the following:

- Less snowpack
- Increased wildfires
- Sea level rise and inland flooding
- Threats to sensitive species (e.g., coho salmon)
- Loss in agricultural productivity (e.g., forestry, wine grape, nursery products, dairy)
- Public health and safety

## 3.1 Cal-Adapt Projections

Table 1. Summary of Cal-Adapt Climate Projections for the North Coast Region

| Effect | Ranges |
|---|---|
| Temperature Change, 1990-2100 | January: 4.1°F to 5°F increase in average temperatures<br>July: 5°F increase in average temperatures<br>(Modeled high temperatures; high emissions scenario) |
| Precipitation | Annual precipitation varies by location with a general decrease throughout the century. Areas of heavy rainfall, like Crescent City and Arcata, are projected to lose 11 to 15 inches per year by the end of the century. Slightly drier places like Mendocino and Ukiah will see a decrease of around 6 inches of precipitation per year by 2100. (CCSM3 climate model; high carbon emissions scenario) |
| Sea Level Rise | By 2100, sea levels may rise up to 55 inches, posing threats to many areas in the region, including Crescent City and the area around Humboldt and Arcata Bays. The increase in acreage vulnerable to 100-year floods due to sea level rise in the region will be 18 percent in both Humboldt and Mendocino counties and 17 percent in Del Norte County. |
| Snowpack | March snow levels in the eastern, higher-elevation portion of the region will drop to almost zero by the 2090s, a decrease of 2 to 10 inches from 2010 levels.<br>(CCSM3 climate model; high carbon emissions scenario) |
| Wildfire Risk | Substantial increase in fire risk is expected throughout the region, with a frequency eight times greater in Del Norte and Humboldt counties and most of Mendocino County. Lake County and northern Mendocino County are projected to have up to 2.5 times greater wildfire frequency. |

[Public Interest Energy Research, 2011. Cal-Adapt. Retrieved from http://cal-adapt.org]

## 3.2 Water Sources

The primary supply of water in California's North Coast region (which includes this climate impact region, plus Siskiyou County) is from the Klamath River and Eel River systems, and accounts for about 17 of the approximately 18 million acre-feet available in 2005 (DWR, 2009). The remaining supply is from groundwater (primarily in coastal areas), reuse, and state or federal projects. Water outflow goes primarily to scenic rivers (again nearly 17 million acre-feet), with a small minority going to urban areas, irrigated agriculture, and managed wetlands. Total storage capacity in the region's reservoirs is 3.78 million acre-feet (DWR, 2009).

## 3.3 Biophysical Characteristics

The landscape of the North Coast region consists primarily of the Coast Mountain Ranges, where peaks vary from 2,000 to 5,000 feet. The Klamath River, which originates in Oregon, winds its way through the north end of the state, culminating 45 miles south of Crescent City. The other major river system, the Eel, extends from Lake County to the Pacific Ocean 15 miles south of Eureka (CERES, 2005). Most of this region, part of the larger Klamath/North Coast Bioregion, is covered by forest. It receives more rainfall than any other part of the state (CDFG, 2007). The region supports diverse wildlife in varied ecosystems that include sand coastlines,

coastal estuaries, grasslands, coastal shrub, freshwater aquatic ecosystems, riparian areas, pine forests, mixed evergreen forests, and redwood forests (CERES, 2005; CDFG, 2007). These ecosystems support human activities from basic services to industries such as forestry and fishing.

## 3.4 Regional Entities

- Air Districts: Lake, Mendocino, North Coast Unified
- Regional Organizations: Del Norte Local Transportation Commission, Humboldt County Association of Governments, Lake County/City Area Planning Council, Mendocino Council of Governments
- Tribal Lands (U.S. EPA, 2011): Big Lagoon, Big Valley, Blue Lake, Coyote Valley, Elk Valley, Hoopa Valley Indian, Hopland, Laytonville, Manchester (Point Arena), Middletown, Pinoleville, Redwood Valley, Resighini, Robinson, Rohnerville, Round Valley, Sherwood Valley, Smith River, Sulphur Bank (El Em), Table Bluff, Trinidad, Upper Lake, Yurok

## 3.5 Major Infrastructure and Selected Regional Resources

Table 2. Major Infrastructure in the North Coast Region

| Types | Names |
|---|---|
| Airports | Andy McBeth, Arcata, Dinsmore, Eureka Municipal, Garberville, Jack McNamara Field, Kneeland Field, Little River, Murray Field, Rohnerville, Shelter Cove, Ward Field, Willits Municipal, Ukiah Municipal |
| Major Hospitals (number of beds) | St. Joseph Hospital-Eureka (146), Mad River Community Hospital (78), Ukiah Valley Medical Center (78), Sutter Coast Hospital (59), Sutter Lakeside Hospital (49), Mendocino Coast District Hospital (49), Humboldt General Hospital (43), Frank R. Howard Memorial Hospital (38), Redwood Memorial Hospital (35), St. Helena Hospital-Clearlake (32) |
| National and State Parks | National: Humboldt Bay National Wildlife Reserve, Redwoods National Park<br>State: Azalea S.N.R.; Clear Lake S.P.; Grizzly Creak Redwoods S.P.; Henry A. Merlo S.R.A.; Humboldt Lagoons S.P.; Humboldt Redwoods S.P.; Jug Handle S.P.; Mallard Redwoods S.P.; Manchester S.P.; Navarro River Redwoods S.P.; Patrick's Point S.P.; Prairie Creek Redwood S.P.; Richardson Grove S.P.; Russian Gulch S.P.; Sinkyone Wilderness S.P.; Van Damme Beach S.P. |
| Ports | Crescent City Harbor, Humboldt Bay Harbor, Noyo Harbor |
| Power Plants (MWs)* | Humboldt Bay (137). |
| Other | Humboldt Nuclear Power Plant (decommissioned); College of the Redwoods; Humboldt State University; Mendocino College |

S.P. = State Park; S.R.A. = State Recreation Area; S.N.R. = State Natural Reserve; MWs = megawatts
*Located within the 100-year flood zone for 1.5-meter sea level rise.

## 3.6 Selected Demographic Data

Table 3. Top Five Employment Sectors in the North Coast Region

| Employment Sector Ranking | | | | | |
|---|---|---|---|---|---|
| **County** | **1** | **2** | **3** | **4** | **5** |
| **Del Norte** | Government | Health Care | Retail Trade | Lodging & Food Services | Construction |
| **Humboldt** | Government | Retail Trade | Health Care | Lodging & Food Services | Construction |
| **Mendocino** | Government | Retail Trade | Health Care | Lodging & Food Services | Construction |
| **Lake** | Government | Health Care | Retail Trade | Lodging & Food Services | Construction |

[CA REAP, 2011]

Table 4. Selected Population Data for the North Coast Region

| | | | | | | Population Below Poverty Level | | |
|---|---|---|---|---|---|---|---|---|
| | Total 2010 Pop. | Pop. <5 years | Percent < 5 years | Pop. ≥65 years | Percent ≥65 years | Estimated - All Ages | Estimated Percent | Margin of Error |
| **County** | **280,490** | **15,529** | **5.5%** | **46,897** | **16.7%** | **50,077** | | |
| Del Norte | 28,610 | 1,703 | 6.0% | 3873 | 13.5% | 5,824 | 23.5 | 4.6 |
| Humboldt | 134,623 | 7,738 | 5.7% | 17725 | 13.2% | 23,752 | 18 | 2.2 |
| Lake | 64,665 | 3,633 | 5.6% | 11440 | 17.7% | 13,438 | 21 | 3.4 |
| Mendocino | 87,841 | 5,347 | 6.1% | 13493 | 15.4% | 16,976 | 19.6 | 3.3 |

[US Census Bureau, 2010, General Population and Housing Characteristics & Small Area Income and Poverty Estimates]

## 3.7 Adaptation Policy Considerations

Many of the stressors already identified as affecting the varied ecosystems in this region are exacerbated by climate change. These include water management, forest management, fire regimes, agricultural and urban development, coastal management and development, and public health (CDFG, 2007). Changes in these areas can result in secondary consequences that affect the local economy and public health and safety.

*Water Management*

Depending on location, parts of this region are projected to experience between 6 and 15 inches less rainfall by 2100 (see Table 1). Reduced rainfall, combined with reductions in snowpack and existing diversions, could result in an altered flow regime in the region. This change would be particularly challenging in this region due to its impact on anadromous fish, such as the coho salmon. Reduced flow, altered timing of flows, and periodic extreme events can result in reduced water quality, habitat destruction, and/or isolation of habitats.

*Forest Management and Fire Regimes*

In 2010, this region was one of the highest timber-producing areas in the state in both volume and value (BOE, 2010). Humboldt and Mendocino counties are two of the highest timber-producing regions in California (BOE, 2010).

Productivity of forestry operations is likely to be affected by climate change due to forest growth rates and wildfire vulnerability. Climate change can affect invasive species, pest populations, and seasonal temperature

and moisture regimes, which can affect productivity of forestry operations. The northern part of the state is projected to have a greater increase in wildfire risk than other parts of the state. This projected increase is based only on climate (e.g., temperature projections) and does not include an assessment of other factors such as vegetation type or fuel load. In the North Coast region, moderate to large increases in large fires (>200 ha) (Westerling et al., 2009; Westerling and Bryant, 2006) are projected in inland areas. A slight decrease in wildfire risk along the coast is projected due to changes in vegetative composition (Lenihen et al., 2006).

Wildfire threatens not only the forestry industry but also the safety of residents. The projected wildfire frequency is a considerable change from current conditions, meaning communities are less likely to be accustomed to the risks of fire and the measures required to address them. Of particular concern for the elderly and children under the age of five (see Table 4) are eye and respiratory illnesses due to air pollution resulting from wildfires, and exacerbation of asthma, allergies, chronic obstructive pulmonary disease (COPD), and other cardiovascular diseases. Wildfire also threatens safety at the wildland-urban interface. With the increase in wildfire likelihood, more residents are likely to be vulnerable to wildfire in the future, and additional policy will need to be developed to address this risk. Smoke management, especially the use of prescribed burning as a fuel reduction tool, should be coordinated with the air districts.

*Agriculture*

The highest value agricultural product of the northernmost areas of the region (Del Norte and Humboldt counties) is timber (California Farm Bureau Federation, 2012). In addition to timber, other products include milk and nursery products. The southern two counties (Mendocino and Lake) produce wine grapes, valued at more than double any other crop.

Each of the products from this region will be affected by climate change differently. Forests will experience changed seasonal patterns that may alter moisture and temperature regimes, both of which may affect growth rates. Further threatening timber production is that temperature and precipitation along with management and invasive species (fuel load) will result in increased fire risk in this region (see above).

For wine grapes, the largest crop in the southern part of the region, climate can affect productivity, as well as the quality of the grape for wine production. North Coast communities should collaborate closely with local agricultural organizations to best support and prepare for changes in this economic sector.

*Coastal Development*

The region is relatively undeveloped on the coast and therefore will generally be resilient as sea level rise occurs. Notable exceptions are the Arcata/Eureka/Fortuna area, which is in a coastal plain subject to flooding, and Crescent City, which is currently susceptible to tsunami. For example, Humboldt County is projected to see an 18-percent increase in coastal inundation by 2100. These communities should carefully assess the potential consequences of these impacts.

Sea level rise is expected to affect vulnerable populations along the coast through the immediate effects of flooding and temporary displacement and longer-term effects of permanent displacement and disruption of local tourism. Some populations do not have the resources to prepare for, respond to, and recover from disasters. These populations are vulnerable to temporary and permanent displacement, drowning, and

property damage, as well as coastal erosion harming recreational activities, tourism, and the tourism industry.

In addition to causing inundation of built structures and public safety hazards, sea level rise can affect tourism. In 2000, over 7 percent of region's employment was dependent on coastal resources (NOEP, 2005), with tourism-based activities representing the largest part of this percentage. Preparing for potential impacts of climate change means taking action to preserve the coastal ecosystems that serve as the tourist attraction. From an ecological perspective, the estuaries at the mouth of the Smith River, Humboldt Bay, and the mouth of the Eel River are of particular concern.

*Equity, Public Health and Socio-economic Impacts*

Extreme heat events are less likely to occur in the North Coast region than in other parts of the state. When they do occur, vulnerable populations may be severely affected because of a historic lack of adaptive capacity having to do with historically milder temperatures. For instance, "low air conditioner ownership" is found along the California coast. Humboldt County has "only medium air conditioner ownership (60-65% of the population)" (English et al., 2007). Humboldt County has moderately high proportions of populations eligible for energy utility financial assistance programs (47 to 55 percent) (English et al., 2007). Households eligible for these programs are an indicator of potential impacts, as these households may be more at risk of not using cooling appliances, such as air conditioning, due to associated energy costs. Del Norte County has a relatively higher poverty level (more than 23%), which suggests residents may not have the material resources needed to prevent, respond, or recover from impacts.

Populations that are isolated in some of the rural areas of this region and may not have the means necessary to recognize impacts and/or evacuate are at increased risk for injuries and death from burns and smoke inhalation and heat-related illnesses. Mendocino County is one of the state's counties with the highest proportion of elderly living alone (English et al., 2007).

**Additional Resources**

- Wildfire resources include the following:
  - California Fire Science Consortium, Northern California Module: http://www.cafiresci.org/home-northern-ca/
  - Northern California Prescribed Fire Council: http://thewatershedcenter.farming.officelive.com/PrescribedFire.aspx
  - NorCal Society of American Foresters: http://norcalsaf.org/
  - California Fire Alliance: http://cafirealliance.org/
  - California FireSafe Council: http://www.firesafecouncil.org/
- California Department of Fish and Game. 2007. *California Wildlife: Conservation Challenges - California's Wildlife Action Plan*. Sacramento. Retrieved from www.dfg.ca.gov/habitats/wdp/
  The Wildlife Action Plan divides the state into regions. The North Coast-Klamath Region overlaps with the North Coast region.

# 4.0 North Region

***Counties***: Lassen, Modoc, Shasta, Siskiyou, Trinity
***Five Largest Cities (CDOF, 2011)***: Redding (90,250); Susanville (17,554); Shasta Lake (10,125); Anderson (10,125); Yreka (7,775)

| Total 2010 Population | |
|---|---|
| **North Region** | **280,490** |
| Lassen | 34,895 |
| Modoc | 9,686 |
| Shasta | 177,223 |
| Siskiyou | 44,900 |
| Trinity | 13,786 |

[U.S. Census Bureau, 2010]

The North region is an inland region that is sparsely settled (280,000+ people), with the exception of the city of Redding (90,000+ people). The region is characterized by rugged mountains and thick forests in the west. The mountain ranges result in a series of microclimates and distinct ecosystems. To the east, the Modoc Plateau supports high desert ecosystems and associated species. The prominent features include Mt. Shasta and Shasta Dam. Major economic activities include tourism and timber.

Climate change impacts that jurisdictions in the North region should consider evaluating include the following:

- Increased wildfire
- Reduced snowpack
- Ecosystem shifts and non-native species
- Flooding
- Economic impact (timber, tourism, grazing)
- Reduced public health due to air pollution (especially for elderly)

## 4.1 Cal-Adapt Projections

Table 5. Summary of Cal-Adapt Climate Projections for the North Region

| Effect | Ranges |
|---|---|
| Temperature Change, 1990-2100 | Winter: Projected increases of 4.1°F to 4.8°F, with larger temperature increases in the mountainous areas in the northeastern portion of the region.<br>Summer: Projected increases of 6°F to 10°F, with larger temperature increases in the mountainous areas in the northeastern portion of the region.<br>(Modeled high temperatures – average of all models; high carbon emissions scenario) |
| Precipitation | Annual precipitation is projected to decline by approximately 2 inches for most of the region.<br>(CCSM3 climate model; high carbon emissions scenario) |
| Snowpack | March snowpack disappears by 2090 for most of the region with the exception of areas near Mt. Shasta.<br>(CCSM3 climate model; high carbon emissions scenario) |
| Wildfire Risk | Substantial increases in the likelihood of wildfires are projected in most of the region, especially in Shasta and Siskiyou counties where risks may be multiplied 6 to 14 times by the end of the century.<br>(GFDL climate model; high carbon emissions scenario) |

[Public Interest Energy Research, 2011. Cal-Adapt. Retrieved from http://cal-adapt.org]

## 4.2 Water Sources

The North region overlaps portions of the Sacramento River, Northern Lahontan, and North Coast hydrologic regions as defined by the California Department of Water Resources (2009). Water supply relies on a mix of imported, regional surface water and groundwater resources for meeting local demand. Overdraft and illegal diversions create challenges for resource management in some areas, contributing to concerns about the preservation of aquatic and riparian habitats (DWR, 2009). Most of Shasta County, the southeastern corner of Siskiyou County, the central portions of Modoc County, and the northwestern area of Lassen County are located in the Sacramento River hydrologic region. In this region there is heavy reliance on groundwater and on the surface water conveyance systems that provide much of the Delta inflow. The easternmost parts of Modoc County and much of Lassen County are located in the North Lahontan hydrologic region (DWR, 2009). The Susan River drains the North Lahontan area and serves as a critical source of water. Trinity County, much of Siskiyou County, and the northwestern portions of Modoc County are in the North Coast hydrologic region. Trinity Lake, located approximately 40 miles northwest of Redding, is the largest reservoir in the North region, containing a volume of over 2.4 million acre-feet. This and other North Coast sources export water to the Sacramento River region via the Clear Creek Tunnel (DWR, 2009). The abundance of rivers and groundwater basins in the region allows for many of the small communities to rely on local resources to meet water demand.

## 4.3 Biophysical Characteristics

The majority of the region is located between 3,000 and 12,000 feet above sea level. Aquatic and riparian resources within the area include Goose Lake, Clear Lake Reservoir, the Klamath River, the Pit River, Shasta Lake, the Sacramento River, Eagle Lake, and Honey Lake (DWR, 2009). Natural vegetation differs based on location within the region. The southwestern portion of the region is characterized by oak, pine, mixed conifer, and hardwood conifer forests accompanied by mixed chaparral and low sage (FRAP, 1998). Areas in Lassen and Modoc counties offer habitat characterized by Joshua trees and juniper woodland, perennial grassland, wetland meadows, and freshwater emergent wetlands (DWR, 2007). The Modoc Plateau and dependent species are declining due to excessive grazing and invasive species.

## 4.4 Regional Entities

- Air Districts: Lassen, Modoc, North Coast Unified, Shasta, Siskiyou
- Regional Organizations: Lassen County Transportation Commission, Modoc County Local Transportation Commission, Shasta County Regional Transportation Planning Association, Trinity County Transportation Commission
- Tribal Lands (U.S. EPA, 2011): Alturas, Big Bend, Cedarville, Fort Bidwell, Karuk, Likely, Lookout, Montgomery Creek, Quartz Valley, Redding, Roaring Creek, Round Valley, Susanville, XL Ranch

## 4.5 Major Infrastructure and Selected Regional Resources

Table 6. Major infrastructure in the North Region

| Types | Names |
|---|---|
| Airports | Trinity Center, Weaverville, Hayfork, Hyampom, Ruth, Butte Valley, Happy Camp, Weed, Dunsmuir Municipal-Mott Airport, Montague-Yreka Rohrer Field, Redding Municipal, Fall River Mills, Shingletown, Alturas Municipal, California Pines, Cedarville, Tulelake Municipal |
| Major Hospitals (number of beds) | Mercy Medical Center Redding (264), Shasta Regional Medical Center (246), Mayers Memorial Hospital (121), Eastern Plumas Hospital-Loyalton Campus (120), Northern California Rehabilitation Hospital (88), Modoc Medical Center (87), Mercy Medical Center of Mt. Shasta (68), Trinity Hospital (51), Banner Lassen Medical Center (38), Shasta County Psychiatric Health Facility (30) |
| Military Facilities | Sierra Army Depot |
| National and State Parks | National: Klamath National Forest, Lassen Volcanic National Park, Modoc National Forest, Shasta National Forest<br>State: Ahjumawi Lava Springs State Park, Castle Crags State Park, Hayden Hill-Silva Flat State Game Refuge, McArthur-Burney Falls Memorial State Park |
| Rail | Coast Starlight (Union Pacific Railroad); Lake County Railroad (Modoc Northern Railroad); Central Oregon & Pacific Railroad (Union Pacific); Yreka Western Railroad (Kyle Railways) |

## 4.6 Selected Demographic Data

Table 7. Top Five Employment Sectors in the North Region

| | Employment Sector Ranking | | | | |
|---|---|---|---|---|---|
| **County** | **1** | **2** | **3** | **4** | **5** |
| **Lassen** | Government | Retail Trade | Health Care & Social Assistance | Other Services | Lodging & Food Services |
| **Modoc** | Government | Farm Employment | Other Services | Retail Trade | Real Estate |
| **Shasta** | Government | Health Care & Social Assistance | Retail Trade | Lodging & Food Services | Other Services |
| **Siskiyou** | Government | Health Care & Social Assistance | Retail Trade | Lodging & Food Services | Other Services |
| **Trinity** | Government | Retail Trade | Lodging & Food Services | Construction | Other Services |

[CA REAP, 2011]

Table 8. Selected Population Data for the North Region

| | Total 2010 Population | Population <5 years | Percent < 5 years | Population ≥65 years | Percent ≥65 years | Population Below Poverty Level | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Estimated - All Ages | Estimated Percent | Margin of Error |
| **County** | **280,490** | **15,529** | **5.5%** | **46,897** | **16.7%** | **50,077** | | |
| Lassen | 34,895 | 1,625 | 4.7% | 3,474 | 10.0% | 4,198 | 16.8 | 4.0 |
| Modoc | 9,686 | 545 | 5.6% | 1,905 | 19.7% | 2,061 | 21.9 | 4.1 |
| Shasta | 177,223 | 10,268 | 5.8% | 29,967 | 16.9% | 31,766 | 18.2 | 2.4 |
| Siskiyou | 44,900 | 2,473 | 5.5% | 8,782 | 19.6% | 9,558 | 21.5 | 3.0 |
| Trinity | 13,786 | 618 | 4.5% | 2,769 | 20.1% | 2,494 | 18.4 | 4.4 |

[U.S. Census Bureau, 2010, General Population and Housing Characteristics & Small Area Income and Poverty Estimates]

## 4.7 Adaptation Policy Considerations

Several aspects of the local economy in this region – including timber harvest, tourism, grazing, and water supply – rely on the local ecosystem. The changes projected for the North region may detrimentally affect these systems as well as threaten public safety and public health.

*Ecosystems and Wildfire*

Changes in temperature, amount of precipitation, and reduction in snowpack (see Table 5) have potential impacts on water quantity and quality. Siskiyou and Trinity counties are home to rivers and streams that support the current and historic range for engangered coho salmon. Alteration of flow regimes and water quality will affect this species (CDFG, 2007). Changes to aquatic systems affect more than just the species, but also economy and human health. Severe Blue Green Algae (BGA) has already affected the Klamath River; local officials have issued health advisories affecting reservoirs used for fishing and boating activities. Thus, BGA, in addition to posing a health risk, threatens tourism. Moreover, Native American tribes that use the river for ceremonial purposes have been affected (CDPH, 2008

In northeast portion of the state (Modoc and Lassen counties), grazing is a major economic activity. Grazing has altered the vegetative pallet of the region by reducing herbaceous vegetation. This change has affected native herbivores and created conditions that provide invasive species a competitive advantage. Riparian areas are also detrimentally affected by livestock grazing (CDFG, 2007).

Climate change can increase forest productivity in the short term, due to increased carbon dioxide and increased temperature. Ultimately, however, reduced water availability, drier conditions, altered pest and invasive species ranges, and increased fire severity and frequency can harm forests. Large increases in wildfire are projected in all parts of the region (Klamath Mountains, Siskiyou Mountains, Southern Cascade Mountains, Modoc Plateau) (Lenihan et al., 2006; Westerling and Bryant, 2006; Westerling et al., 2009).

Wildfire affects not only the local ecosystem and timber industry, but also public health and safety. Of particular concern for the elderly and children under the age of five (see Table 8) are eye and respiratory illnesses due to air pollution resulting from wildfires, and exacerbation of asthma, allergies, chronic

obstructive pulmonary disease (COPD), and other cardiovascular diseases. Fires would not only jeopardize safety and property, but also destroy resources for the timber industry and affect the local economy.

*Water Resources*

In addition to affecting aquatic ecosystems, shorter rainfall events and rapid snowmelt will reduce the region's water supply. Recreation and tourism in the region are likely to suffer due to lower water levels in waterways and reservoirs and declining snowpack in north-central areas of the region. Unstable working conditions in the tourism industry may increase the economic vulnerability of employees in this industry.

Rapid snowmelt events and intense rainfall can result in flooding. Flood events may overwhelm water treatment and wastewater management facilities and risk exposing communities to contaminated water resources. Higher temperatures and early snowmelt may also lengthen the life and impact of vector-borne diseases.

*Equity, Health, and Socio-economic Impacts*

Households eligible for energy utility financial assistance programs are an indicator of potential impacts. These households may be more at risk of not using cooling appliances, such as air conditioning, due to associated energy costs. Siskiyou and Trinity counties have some of the state's highest proportions of population eligible for energy assistance (56 to 63 percent). Lassen County also has a moderately high proportion of population eligible (47 to 55 percent) (English et al, 2007). Modoc and Siskiyou counties have relatively higher poverty levels (more than 21%), which suggests residents may not have the material resources needed to prevent, respond, or recover from impacts.

The second largest employment sector in Modoc County is farming. In Trinity, Siskiyou, and Lassen counties, lodging and food are in the top five employment sectors, indicating that tourism is an important industry. Foothills and mountainous communities of this region may be particularly subject to respiratory problems and heat stress due to a combination of higher ozone levels, higher elevations, and increasing temperatures in these areas (English et al., 2007; Drechsler et al., 2006). In areas such as these, conditions conducive to ozone formation are projected to increase by as much as 25 to 80 percent by 2100 (Drechsler et al., 2006, Karl and Roland-Holst, 2008). Those most vulnerable to high levels of ozone and particulate matter include people who work or spend a lot of time outdoors, such as employees of the agricultural and the tourism industries. People over the age of 65 have the largest increase in mortality with increased concentrations of ozone (Medina-Ramon and Schwartz, 2008). Trinity, Modoc, Siskiyou and Shasta counties have a relatively high percentage of population older than 65. This population is more vulnerable to heat events and air quality problems.

Modoc County is one of the state's counties with the highest proportion of elderly living alone (English et al., 2007). Populations that are isolated in some of the rural areas of this region and may not have the means necessary to recognize impacts and/or evacuate are at increased risk for injuries and death from burns and smoke inhalation and heat-related illnesses.

**Additional Resources**

- Wildfire resources include the following:
  - California Fire Science Consortium, Northern California Module: http://www.cafiresci.org/home-northern-ca/
  - Northern California Prescribed Fire Council: http://thewatershedcenter.farming.officelive.com/PrescribedFire.aspx
  - NorCal Society of American Foresters: http://norcalsaf.org/
  - Quincy Library Group: http://qlg.org/
  - California Fire Alliance: http://cafirealliance.org/
  - California FireSafe Council: http://www.firesafecouncil.org/
- California Department of Fish and Game. 2007. *California Wildlife: Conservation Challenges - California's Wildlife Action Plan*. Sacramento. Retrieved from www.dfg.ca.gov/habitats/wdp/

The Wildlife Action Plan divides the state into regions. The North Coast-Klamath and Modoc Plateau Regions overlap with the North region.

# 5.0 Bay Area Region

***Counties***: Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, Sonoma
***Five Largest Cities (CDOF, 2011)***: San Jose (958,789); San Francisco (812,820); Oakland (392,932); Fremont (215,711); Santa Rosa (168,856)

| Total 2010 Population | |
|---|---|
| **Bay Area Region** | **7,150,739** |
| Alameda | 1,510,271 |
| Contra Costa | 1,049,025 |
| Marin | 252,409 |
| Napa | 136,484 |
| San Francisco | 805,235 |
| San Mateo | 718,451 |
| Santa Clara | 1,781,642 |
| Solano | 413,344 |
| Sonoma | 483,878 |

[U.S. Census Bureau, 2010]

The Bay Area is a heavily urbanized region (over 7 million people). The predominant feature of this region is San Francisco Bay and the miles of shoreline, both on the Pacific coast and along the bay, extending north to Sonoma County, inland to the Delta, and south to San Jose. The urbanized areas are concentrated primarily around the bay. To the north and south, the region is characterized by low coastal mountains (CDFG, 2007). Sonoma and Napa counties produce wine grapes valued over $850,000,000 in 2010 (California Farm Bureau Federation, 2012). To the east, Solano and Contra Costa counties are on the western edge of the low-lying California Delta. The Delta is a unique setting that faces specific threats as a result of climate change. The parts of the Bay Area Region also located in the California Delta are included in an additional region, the Bay-Delta Region (see Section 7.0).

Communities in the Bay Area should consider evaluating the following climate change impacts:

- Increased temperatures
- Reduced precipitation
- Sea level rise – coastal inundation and erosion
- Public health – heat and air pollution
- Reduced agricultural productivity (e.g., wine grapes)
- Inland flooding

## 5.1 Cal-Adapt Projections

Table 9. Summary of Cal-Adapt Climate Projections for the Bay Area Region

| Effect | Ranges |
|---|---|
| Temperature Change, 1990-2100 | January: 4°F to 5°F increase in average temperatures<br>July: 5°F to 6°F increase in average temperatures<br>(Modeled high temperatures – average of all models; high carbon emissions scenario) |
| Precipitation | Precipitation varies widely in this region, with annual totals over 40 inches in northern Sonoma County to roughly 15 inches in the eastern portions of Solano and Contra Costa counties. A moderate decline in annual rainfall, 4 to 5 inches by 2090, is projected throughout the region.<br>(CCSM3 climate model; high carbon emissions scenario) |
| Sea Level Rise | By 2100, sea levels may rise up to 55 inches, posing considerable threats to coastal areas and particularly to low-lying areas adjacent to San Francisco Bay. The number of acres vulnerable to flooding is expected to increase 20 to 30 percent in most parts of the Bay Area, with some areas projected for increases over 40 percent. Coastal areas are estimated to experience an increase of approximately 15 percent in the acreage vulnerable to flooding. |
| Fire Risk | There is little change in projected fire risk in this region, save for the slight increases expected in western Marin County.<br>(GFDL climate model; high carbon emissions scenario) |

[Public Interest Energy Research, 2011. Cal-Adapt. Retrieved from http://cal-adapt.org]

## 5.2 Water Sources

Approximately 70 percent of the water used in the region is imported, with another 15 percent supplied via groundwater. The imported water comes from a variety of sources, including the Russian River (4 percent); the Delta (approximately 32 percent, via San Luis Reservoir, North Bay Aqueduct, Contra Costa Canal, South Bay Aqueduct); Lake Berryessa (5 percent); Mokelumne River (25 percent); and Tuolumne River (33 percent). The vast majority of these water sources (e.g., Delta sources, Mokelumne River, Tuolumne River) originate in the Sierra Nevada, meaning that climate change impacts on snowpack may have a dramatic impact on Bay Area water supply. Total reservoir storage capacity in the Bay Area is 746,000 acre-feet (DWR, 2009).

## 5.3 Biophysical Characteristics

The Bay Area region is located in an area characterized by a Mediterranean climate, with warmer summer temperatures observed in the eastern portions of the region. San Francisco Bay and the associated estuarine ecosystem sit at the center of the region and serve as the outlet for the Sacramento and San Joaquin rivers. This estuary supports rich biodiversity, including many special-status species (CDFG, 2007).

The eastern portions of Contra Costa and Solano counties meet the western edge of the area commonly known as the Delta. This area has subsided and has elevations below sea level.

The topography in the Bay Area region reaches to over 4,000 feet in the Coastal Range and falls to the low-lying areas along the coast and bay. In the west, the dominant vegetation is coniferous forest with a mix of hardwoods. To the east, shrubs and grasses begin to emerge (FRAP, 1998; FRAP, 2003).

## 5.4 Regional Entities

- Air Districts: Bay Area Air Quality Management District
- Regional Organizations: Association of Bay Area Governments, Metropolitan Transportation Commission
- Tribal Lands (U.S. EPA, 2011): Dry Creek, Stewarts Point

## 5.5 Major Infrastructure and Selected Regional Resources

Table 10. Major Infrastructure in the Bay Area Region

| Types | Names |
|---|---|
| Airports | International: Oakland International, San Francisco International, San Jose International<br>General Aviation: Angwin-Parrett Field, Byron, Concord/Buchanan Field, Cloverdale Municipal, Gnoss Field, Half Moon Bay, Hayward Executive, Healdsburg Municipal, Livermore Municipal, Napa County, Nut Tree Airport, Ocean Ridge, Palo Alto, Petaluma Municipal, Rio Vista Municipal, San Carlos, Sonoma County, Sonoma Valley, South County |
| Major Hospitals (number of beds) | Sonoma Developmental Center (1,413), Napa State Hospital (1,362), Stanford Hospital (1,226), Laguna Honda Hospital and Rehabilitation Center (805), San Francisco General Hospital (598), UCSF Medical Center (582), Santa Clara Valley Medical Center (574), N. M. Holderman Memorial Hospital (536), Jewish Home (491), Kaiser Hospital and Rehabilitation Center-Vallejo (475) |
| Military Facilities | Alameda Naval Air Station (closed), Camp Parks, Coast Guard Island, Mare Island Naval Shipyard(closed), Moffett Federal Airfield, Oakland Naval Supply Center (closed), Travis Air Force Base |
| National and State Parks | National: Golden Gate National Recreation Area, Gulf of the Farallones National Marine Sanctuary, Muir Woods National Monument, Point Reyes National Seashore, San Francisco Bay National Wildlife Refuge Complex (7 sites)<br>State: Albany State Marine Reserve; Angel Island S.P.; Annadel S.P.; Ano Nuevo S.P.; Armstrong Redwoods Natural Reserve; Big Basin Redwoods S.P.; Bothe-Napa Valley S.P.; Butano S.P.; Castle Rock S.P.; China Camp S.P.; Eastshore S.P.; Emeryville Crescent State Marine Reserve; Henry W. Coe S.P.; Kruse Rhododendron Natural Reserve; Mount Diablo S.P.; Mount Tamalpais S.P.; Pacheco S.P.; Portola Redwoods S.P.; Robert Louis Stevenson S.P.; Robert W. Crown Memorial Beach; Salt Point S.P.; Samuel P. Taylor S.P.; San Bruno Mountain S.P.; Sonoma Coast S.P.; Sugarloaf Ridge S.P.; Tomales Bay S.P. |
| Passenger Rail | Altamont Commuter Express, Amtrak, Bay Area Rapid Transit, Caltrain, San Francisco Muni Metro, Santa Clara Valley Transportation Authority |

Table 10 (cont'd). Major Infrastructure in the Bay Area Region

| Types | Names |
|---|---|
| Ports | Bulk and Container: Benicia, Oakland, Pittsburg, Richmond, Redwood City, San Francisco<br>Other: Pillar Point Harbor, Porto Bodega Marina |
| Power Plants (MWs)* | Duke Energy Oakland (165), Newby Island 2 (6.5), Pittsburg (1310), GWF Power Systems L.P. (22.8), Foster-Wheeler Martinez Cogen L.P. (114), Nove Power Plant (3), American Canyon Power Plant (1.7), Hunters Point (215), United Cogen Inc. (31), Gianera (49.5), Gas Recovery Systems-Fremont (3.75), Solano Cogen (1.45) |
| Other | Over 50 colleges and universities; five refineries; Pittsburg Power Plant; Lawrence Berkeley National Laboratory; Lawrence Livermore National Laboratory; Sandia National Laboratories |

S.P. = State Park; MWs = megawatts

*Located within the 100-year flood zone for 1.5-meter sea level rise

## 5.6 Selected Demographic Data

Table 11. Top Five Employment Sectors in the Bay Area Region

| | Employment Sector Ranking | | | | |
|---|---|---|---|---|---|
| **County** | **1** | **2** | **3** | **4** | **5** |
| **Alameda** | Government | Professional & Technical Services | Health Care | Retail Trade | Manufacturing |
| **Contra Costa** | Retail Trade | Health Care | Government | Professional & Technical Services | Finance & Insurance |
| **Marin** | Professional & Technical Services | Health Care | Retail Trade | Government | Other Services |
| **Napa** | Manufacturing | Government | Lodging & Food Services | Health Care | Retail Trade |
| **San Francisco** | Professional & Technical Services | Government | Lodging & Food Services | Finance & Insurance | Health Care |
| **San Mateo** | Professional & Technical Services | Retail Trade | Health Care | Finance & Insurance | Government |
| **Santa Clara** | Manufacturing | Professional & Technical Services | Government | Retail Trade | Health Care |
| **Solano** | Government | Retail Trade | Health Care | Lodging & Food Services | Construction |
| **Sonoma** | Government | Health Care | Retail Trade | Professional & Technical Services | Manufacturing |

[CA REAP, 2011]

Table 12. Selected Population Data for the Bay Area Region

| | Total 2010 Population | Population <5 years | Percent < 5 years | Population ≥65 years | Percent ≥65 years | Population Below Poverty Level | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Estimated - All Ages | Estimated Percent | Margin of Error |
| **Bay Area** | **7,150,739** | **447,811** | **6.3%** | **878,229** | **12.3%** | **781,399** | | |
| Alameda | 1,510,271 | 97,652 | 6.5% | 167,746 | 11.1% | 200,273 | 13.5 | 1.0 |
| Contra Costa | 1,049,025 | 67,018 | 6.4% | 130,438 | 12.4% | 97,544 | 9.3 | 0.9 |
| Marin | 252,409 | 13,932 | 5.5% | 42,192 | 16.7% | 22,456 | 9.2 | 1.5 |
| Napa | 136,484 | 8,131 | 6.0% | 20,594 | 15.1% | 14,189 | 10.7 | 1.8 |
| San Francisco | 805,235 | 35,203 | 4.4% | 109,842 | 13.6% | 100,910 | 12.8 | 1.1 |
| San Mateo | 718,451 | 46,360 | 6.5% | 96,262 | 13.4% | 49,908 | 7.0 | 0.9 |
| Santa Clara | 1,781,642 | 124,464 | 7.0% | 196,944 | 11.1% | 186,051 | 10.6 | 0.7 |
| Solano | 413,344 | 26,852 | 6.5% | 46,847 | 11.3% | 49,159 | 12.2 | 1.4 |
| Sonoma | 483,878 | 28,199 | 5.8% | 67,364 | 13.9% | 60,909 | 12.8 | 1.2 |

[U.S. Census Bureau, 2010, General Population and Housing Characteristics & Small Area Income and Poverty Estimates]

## 5.7 Adaptation Policy Considerations

Large urban areas are prone to specific secondary climate change impacts due to population density and urban settlement patterns. In the Bay Area region, the location of the urbanized area near a bay that serves as the mouth of two major river networks creates the potential for additional impacts. Outside of the urbanized region, ecosystem shifts and impacts on agriculture, specifically wine grapes, may be experienced.

*Sea Level Rise*

Since much of the urbanized part of region is near the ocean or bay, sea level rise will significantly affect development and infrastructure. This is likely to be the greatest threat from climate change to the Bay Area. A 1.4-meter rise in sea level will increase the population vulnerable to a 100-year coastal storm from 10,610 to 13,730 (CCCC, 2009).

The San Francisco Bay Conservation and Development Commission (BCDC) evaluated vulnerability to sea level rise in the region and potential adaptation strategies. Key issues identified by BCDC for the region include the following:

- A "55-inch rise in sea level would place an estimated 270,000 people in the Bay Area at risk from flooding, 98 percent more than are currently at risk. The economic value of Bay Area shoreline development (buildings and their contents) at risk from a 55-inch rise in sea level is estimated at $62 billion…" (BCDC, 2011, p. 3).
- Coastal flooding presents a risk to major transportation infrastructure in the region including freeways, rail lines, ports, and airports (especially San Francisco and Oakland).
- "The impacts of climate change are expected to substantially alter the Bay ecosystem by inundating or eroding wetlands and transitional habitats, altering species composition, changing freshwater inflow,

and impairing water quality. Changes in salinity from reduced freshwater inflow may adversely affect fish, wildlife and other aquatic organisms in intertidal and subtidal habitats. The highly developed Bay shoreline constrains the ability of tidal marshes to migrate landward, while the declining sediment supply in the Bay reduces the ability of tidal marshes to grow upward as sea level rises" (BCDC, 2011, p. 5).

With the large number of local and special purpose governments in the region, addressing the sea level rise problem will require regional collaboration involving the California Coastal Commission and San Francisco Bay Conservation and Development Commission. The San Francisco Planning + Urban Research Association (2012) has recommended the following actions for addressing climate change:

- Barrier(s) or tidal barrage(s) to manage tidal flows in and out of San Francisco Bay (at the Golden Gate or in smaller, strategic parts of the bay)
- Coastal armoring with linear protection, such as levees and seawalls, to fix the shoreline in its current place
- Elevated development in which the height of land or existing development is raised and protected with coastal armoring
- Floating development on the surface of the water, or development that may be floated occasionally during a flood, making it largely invulnerable to changing tides
- Floodable development designed to withstand flooding or to retain stormwater
- Living shorelines with wetlands that absorb floods, slow erosion, and provide habitat
- Managed retreat that safely removes settlement from encroaching shorelines, allowing the water to advance unimpeded, and bans new development in areas likely to be inundated

Alameda and San Mateo counties could see significant increases in the number of United States Environmental Protection Agency (U.S. EPA)-regulated sites at risk for sea level rise, including Superfund sites, hazardous waste generators, facilities required to report emissions for the Toxics Release Inventory, facilities regulated under the National Pollutant Discharge Elimination System (NPDES), major dischargers of air pollutants with Title V permits, and brownfield properties (CCCC, 2009).

Sea level rise is also expected to affect vulnerable populations along the coast through the immediate effects of flooding and temporary displacement and longer-term effects of permanent displacement and disruption of local tourism. Of particular concern are populations that do not have the resources to prepare for, respond to, and recover from disasters. Impacts could include temporary and/or permanent displacement, drowning and property damage, and coastal erosion harming recreational activities, tourism, and the tourism industry.

Vulnerable populations living in institutional settings are disproportionately vulnerable during evacuations from disasters. For instance, Solano and Marin counties have a high proportion of elderly living in nursing homes that could be affected (English et al., 2007).

*Flooding*

The risk of flooding is highest for the inland, low-lying areas in the eastern part of the region. Reduced snowpack and increased number of intense rainfall events in the Northern Sierra are likely to put additional

pressure on water infrastructure, including the Delta levees, which are already vulnerable (DWR, 2011). These impacts increase the chance of flooding associated with breached levees or dams (e.g., in the Sacramento-San Joaquin Delta). Flooding and damage to infrastructure can put large populations in adjacent regions at risk (CDPH, 2008), including:

- The elderly and children less than five years of age, who are isolated or dependent on others for evacuation.
- Populations that may lack the resources or knowledge to prepare or respond to disaster due to language or economic status, including having access to transportation, which would allow them to escape, at least temporarily, flooding.
- Vulnerable populations living in institutional settings who are particularly vulnerable during evacuations from disasters. For instance, Solano, and Marin counties have a high proportion of elderly living in nursing homes that could be affected (English et al., 2007).

*Equity, Health, and Socio-economic Impacts*

Some of the state's highest percentages of impervious surfaces are in the urban areas of the San Francisco Bay Area, increasing the potential impacts of heat islands (English et al., 2007)**.** Santa Clara, Alameda, San Francisco, and Contra Costa counties rank fifth, sixth, ninth, and tenth in the absolute numbers of the elderly and children less than five years of age. These two populations are most likely to suffer from heat-related illnesses and heat events (English et. al, 2007).

The highest risk of heat-related illness occurred in the usually cooler regions found in coastal counties and not in the Central Valley where the highest actual temperatures were experienced (Gershunov and Cayan, 2008; CDPH, 2008). Because of a lack of acclimatization, the largest mortality rate increases in California are expected in coastal cities such as San Francisco (CNRA, 2009).

Lodging and food services are among the top five employment sectors in Napa, San Francisco, and Solano counties, indicating that may be a significant number of employees who work in the tourism industry/outdoors. Sea-level rise may impact employees in the tourism industry. Air quality and heat events may impact outdoor workers.

*Fire*

A slight increase in fire occurrence is projected for the region. This increase is projected to be largest in the northeastern part of the region. Despite moderate increases in fire risk, huge increases in fire damages are projected due to high population in fire-vulnerable areas (Bryant and Westerling, 2009). Along with impacts associated with temporary and/or permanent displacement, long-term impacts on the elderly and children under the age of five are of concern. Eye and respiratory illnesses due to air pollution resulting from wildfires, and exacerbation of asthma, allergies, chronic obstructive pulmonary disease (COPD), and other cardiovascular diseases, are likely to increase.

*Ecosystem and Agriculture*

Alteration of temperature and precipitation regimes changes the seasons as experienced by plants and animals. These changes are expected to affect the wine industry because the wine grape is a crop that requires a fairly narrow range of climate conditions (Todorov, 2011). These changes might affect not only wine grape growers, but also the businesses and residents dependent on this industry. Communities reliant on the wine industry as an employment base, tourist attraction, or local economic base should closely collaborate with vintner associations and other local agricultural organizations to best understand the risk and support grower efforts to adapt. Communities also may need to plan for a future in which wine grapes and associated activities make up a smaller part of their local economy.

**Additional Resources**

- Equity, Health, and Socio-economic Impacts
  - San Francisco's Healthy Development Measurement Tool (www.theHDMT.org) provides health-based rationales, goals, and indicators applicable to other jurisdictions. The San Francisco Public Health Department has also used it to generate a wide range of health-oriented maps, including proximity to farmers' markets, noise levels, bike collisions, and truck routes.
  - Issues and Opportunities Papers for the City of Richmond's upcoming general plan update (www.cityofrichmondgeneralplan.org/docs.php?ogid=1000000207) include a baseline assessment built largely from the framework of the Healthy Development Measurement Tool described above.
  - The Oakland Health Profile (2004) includes maps comparing diabetes and childhood asthma hospitalization rates across the city and county (Public Health Law and Policy, How to Create a Healthy General Plan, 2008).
  - The San Jose area has a Health Heat Watch Warning System in place (CDPH, 2008).
- Wildfire Resources
  - California Fire Science Consortium, Central & South Coast Module: http://www.cafiresci.org/home-central-and-southern-ca/
  - California Fire Alliance: http://cafirealliance.org/
  - California FireSafe Council: http://www.firesafecouncil.org/
- Biodiversity and Ecosystems
  - California Department of Fish and Game. 2007. *California Wildlife: Conservation Challenges - California's Wildlife Action Plan*. Sacramento. Retrieved from www.dfg.ca.gov/habitats/wdp/

  The Wildlife Action Plan divides the state into regions. The Marine and Central Valley and Bay-Delta Regions overlap with the Bay Area region.

# 6.0 Northern Central Valley Region

***Counties***: Butte, Colusa, Glenn, Madera, Merced, Sacramento, San Joaquin, Stanislaus, Sutter, Tehama, Yolo, Yuba

***Five Largest Cities (CDOF, 2011)***: Sacramento (469,566); Stockton (293,515); Modesto (202,290); Elk Grove (154,594); Chico (86,900)

| Total 2010 Population | |
|---|---|
| **Northern Central Valley** | **3,725,950** |
| Butte | 220,000 |
| Colusa | 21,419 |
| Glenn | 28,122 |
| Madera | 150,865 |
| Merced | 255,793 |
| Sacramento | 1,418,788 |
| San Joaquin | 685,306 |
| Stanislaus | 514,453 |
| Sutter | 94,737 |
| Tehama | 63,463 |
| Yolo | 200,849 |
| Yuba | 72,155 |

[U.S. Census Bureau, 2010]

The Northern Central Valley is a largely agricultural, inland region with over 3.7 million people, with substantial cities, the largest being the state capitol, Sacramento (469,000+ people). The central portion of the region is defined by the Delta, with inland marshes intermingled with agriculture, interspersed with cities along transport corridors. The region contains the Port of Stockton, the most inland port for ocean-going vessels, approximately 80 miles from the Golden Gate Bridge. The Delta is a unique setting that faces specific threats as a result of climate change. The parts of the Northern Central Valley Region also located in the California Delta are included in an additional region, the Bay-Delta Region (see Section 7.0). Agriculture is the predominant economic activity. The agricultural operations in this region include rice, dairy, and nut trees (almond and walnut) (California Farm Bureau Federation, 2012). The region's agricultural activity is one of the most productive in the nation.

In the Northern Central Valley region, communities will need to assess vulnerability to the following impacts:

- Temperature increases – particularly nighttime temperature
- Reduced precipitation
- Flooding – increase flows, snowmelt, levee failure in the Delta
- Reduced agricultural productivity (e.g., nut trees, dairy)
- Reduced water supply
- Wildfire in the Sierra foothills
- Public health and heat

## 5.1 Cal-Adapt Projections

Table 13. Summary of Cal-Adapt Climate Projections for Northern Central Valley

| Effect | Ranges |
|---|---|
| Temperature Change, 1990-2100 | Winter: Projected to increase between 8°F and 12°F, with larger temperature increases being projected for the southern portions of the region.<br>Summer: Projected to increase of 12°F to 15°F, with the largest increases anticipated in the northern parts of the region.<br>(Modeled high temperatures – average of all models; high carbon emissions scenario) |
| Precipitation | Annual precipitation is projected to decline by approximately 3 to 6 inches across the region, though the northern areas are anticipated to experience the largest decrease.<br>(CCSM3 climate model; high carbon emissions scenario) |
| Wildfire Risk | By 2085, the north and eastern portions of the region will experience an increase in wildfire risk, more than 4 times current levels in some areas.<br>(GFDL model, high emissions scenario) |

[Public Interest Energy Research, 2011. Cal-Adapt. Retrieved from http://cal-adapt.org]

## 6.2 Water Sources

Two rivers, the San Joaquin and Sacramento, run through this region. The rivers originate from snowmelt in the Sierra Nevada and the mountainous regions in the north and flow toward San Francisco Bay, where the flows eventually reach the Pacific Ocean. The confluence of the rivers occurs in Sacramento-San Joaquin Delta.

Water moves through the region through natural waterways as well as a network of canals and reservoirs. The reservoir and canal systems that hold much of the region's water allow it to be leveraged for energy generation and recreational use (DWR, 2009). The water supply network for the region is highly complex. One third of the regional water supply relies on groundwater pumping, which can increase during drought periods when more water may be pumped to make up for surface water shortfalls. For the remaining majority of the water supply, there is heavy reliance on the surface water conveyance systems that provides the inflow to the Sacramento-San Joaquin Delta (also known as the California Delta or the Bay-Delta

The Delta serves as a primary water source for the entire state, serving approximately 25 million residents as far south as San Diego and an agricultural industry valued at over $25 billion (San Diego County Water Authority, *n.d.)*. These supplies are delivered through the State Water Project, the Central Valley Project, and a host of other federal water projects. In the Delta, the system of canals, bordered by levees, also serves to deliver floodwater, support commercial fishing, provide for recreational activities, and maintain ecosystem health. The network of reservoirs within the region also plays a vital role in preventing saltwater intrusion in the California Delta by providing freshwater flushes during the summer and fall (DWR, 2009).

The Northern Central Valley region overlaps three hydrologic regions as defined by the Department of Water Resources: San Joaquin River, Sacramento River, and Sacramento-San Joaquin Delta. Reservoir storage capacity in the Sacramento River and San Joaquin River hydrologic regions is 16.15 and 11.48 million acre-feet, respectively (DWR, 2009).

## 5.3 Biophysical Characteristics

While elevations range from 3,000 to 12,000 feet in the eastern areas of Madera, Butte, Sutter, and Tehama counties, areas located within the primary Delta zone in southern Yolo County and eastern Sacramento and San Joaquin counties are at or below sea level (CDFG, 2007). On average, elevation in the Northern Central Valley region is less than 300 feet above sea level. The region is bordered by the Sierra Nevada to the east and the coastal mountain ranges to the west. The extensive natural vegetation in the region is dominated by grasslands and scrub but also contains hardwood and coniferous forest and woodland (FRAP, 1998).

Major rivers include the Sacramento, San Joaquin, Feather, Merced, and Stanislaus. Many of the large lakes in the region are the result of river damming as part of reservoir and water project construction.

## 6.4 Regional Entities

- Air Districts: Butte, Colusa, Feather River, Glenn, San Joaquin Valley Unified, Tehama, Yolo-Solano
- Regional Organizations: Butte County Association of Governments, Tehama County Transportation Commission, Glenn County Transportation Commission, Colusa County Transportation Commission, Sacramento Area Council of Governments, San Joaquin Council of Governments, Stanislaus Council of Governments (StanCOG), Merced County Association of Governments, Madera County Transportation Commission
- Tribal Lands (U.S. EPA, 2011): Berry Creek, Colusa (Cachil Dehe), Cortina, Enterprise, Grindstone Creek, Mooretown, North Fork, Picayune, Rumsey

## 6.5 Major Infrastructure and Selected Regional Resources

Table 14. Major Infrastructure in the Northern Central Valley Region

| Types | Names |
|---|---|
| Airports | International: Sacramento International Airport<br>General Aviation: Chico Municipal Airport, Oroville Municipal Airport, Paradise Airport, Ranchaero Airport, Richvale Airport, Colusa County Airport, Willows-Glenn County Airport, Haigh Field, Madera Municipal Airport, Chowchilla Airport, Merced Regional Airport, Castle Airport, Gustine Airport, Los Banos Municipal Airport, Sacramento Mather Airport, Sacramento Executive Airport, Stockton Metropolitan Airport, Escalon Airport, Lodi Airport, Tracy Municipal Airport, Modesto City-County Airport, Oakdale Airport, Patterson Airport, Turlock Airpark, Sutter County Airport, Red Bluff Municipal Airport, Corning Municipal Airport, Watts Woodland Airport, UC Davis University Airport, Yolo County Airport, Borges Airport, Yuba County Airport, Brownsville Aero Airport |
| Major Hospitals (number of beds) | UC Davis Medical Center (613), Memorial Hospital Medical Center-Modesto (423), Fremont Medical Center (396), Doctors Medical Center (394), Mercy San Juan Hospital (370), St. Joseph's Medical Center of Stockton (359), Sutter Memorial Hospital (348), Mercy General Hospital (342), Children's Hospital Central California (338), Methodist Hospital of Sacramento (333) |

Table 14 (cont'd). Major Infrastructure in the Northern Central Valley Region

| Types | Names |
|---|---|
| Military Facilities | Beale Air Force Base, Castle Air Force Base, Defense Distribution Depot San Joaquin, Mather Air Force Base, McClellan Air Force Base, Coast Guard Air Station Sacramento |
| National and State Parks | National: Lassen National Forest, Lassen Volcanic National Park, Mendocino National Forest, Yosemite National Park<br>State: Bidwell-Sacramento S.P.; Great Valley Grasslands S.P.; Pacheco S.P.; Caswell Memorial S.P.; Henry W. Coe S.P.; Sutter Buttes S.P. |
| Ports | Port of Sacramento, Port of Stockton, Rio Vista Harbor |
| Rail | Cal-P (Central Pacific), SP West Valley Line (California Northern Railroad), Feather River (Union Pacific), Altamont Commuter Express (Union Pacific Railroad), San Joaquin (Union Pacific Railroad), Sacramento Regional Light Rail System, Central California Traction Company (Union Pacific & BNSF Railway), Modesto & Empire Traction Company (Beard Land & Investment Company), Sierra Northern Railway (Sierra Railroad Company) |

S.P. = State Park

## 6.6 Selected Demographic Data

Table 15. Top Five Employment Sectors in the Northern Central Valley Region

| | Employment Sector Ranking | | | | |
|---|---|---|---|---|---|
| **County** | **1** | **2** | **3** | **4** | **5** |
| **Butte** | Health Care | Government | Retail Trade | Other Services | Lodging & Food Services |
| **Colusa** | Government | Farm Employment | Manufacturing | Lodging & Food Services | Wholesale Trade |
| **Glenn** | Government | Farm Employment | Retail Trade | Other Services | Lodging & Food Services |
| **Madera** | Government | Health Care | Retail Trade | Farm Employment | Manufacturing |
| **Merced** | Government | Retail Trade | Manufacturing | Health Care | Farm Employment |
| **Sacramento** | Government | Health Care | Retail Trade | Professional & Technical Services | Finance & Insurance |
| **San Joaquin** | Government | Health Care | Retail Trade | Manufacturing | Lodging & Food Services |
| **Stanislaus** | Government | Retail Trade | Health Care | Manufacturing | Lodging & Food Services |
| **Sutter** | Retail Trade | Health Care | Government | Lodging & Food Services | Farm Employment |
| **Tehama** | Government | Retail Trade | Farm Employment | Health Care | Manufacturing |
| **Yolo** | Government | Retail Trade | Health Care | Professional & Technical Services | Transportation & Warehousing |
| **Yuba** | Government | Retail Trade | Farm Employment | Construction | Other Services |

[CA REAP, 2011]

Table 16. Selected Population Data for the Northern Central Valley Region

| | Total 2010 Population | Popula-tion <5 years | Percent < 5 years | Population ≥65 years | Percent ≥65 years | Population Below Poverty Level | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Estimated - All Ages | Estimated Percent | Margin of Error |
| **Northern Central Valley** | **3,725,950** | **276,063** | **7.4%** | **414,921** | **11.1%** | **679,162** | | |
| Butte | 220,000 | 12,409 | 5.6% | 33,817 | 15.4% | 43,392 | 20.1 | 2.2 |
| Colusa | 21,419 | 1,841 | 8.6% | 2,495 | 11.6% | 3,161 | 14.9 | 3.0 |
| Glenn | 28,122 | 2,178 | 7.7% | 3,737 | 13.3% | 4,890 | 17.6 | 3.6 |
| Madera | 150,865 | 11,983 | 7.9% | 17,262 | 11.4% | 30,912 | 21.7 | 3.3 |
| Merced | 255,793 | 22,226 | 8.7% | 23,960 | 9.4% | 58,212 | 23.1 | 2.3 |
| Sacramento | 1,418,788 | 101,063 | 7.1% | 158,551 | 11.2% | 234,470 | 16.7 | 1.1 |
| San Joaquin | 685,306 | 54,228 | 7.9% | 71,181 | 10.4% | 128,331 | 19.0 | 1.5 |
| Stanislaus | 514,453 | 39,779 | 7.7% | 54,831 | 10.7% | 100,554 | 19.7 | 1.5 |
| Sutter | 94,737 | 7,153 | 7.6% | 11,990 | 12.7% | 15,780 | 16.8 | 2.7 |
| Tehama | 63,463 | 4,409 | 6.9% | 10,071 | 15.9% | 12,810 | 20.4 | 3.3 |
| Yolo | 200,849 | 12,577 | 6.3% | 19,771 | 9.8% | 31,942 | 16.4 | 2.3 |
| Yuba | 72,155 | 6,217 | 8.6% | 7,255 | 10.1% | 14,708 | 20.7 | 3.5 |

[U.S. Census Bureau, 2010, General Population and Housing Characteristics & Small Area Income and Poverty Estimates]

## 6.7 Adaptation Policy Considerations

Waterways in the Northern Central Valley region drain to the California Delta. Part 1 of the APG identifies the California Delta as a special sector due to the distinctiveness of the setting and the challenges faced there. The issues, particularly flooding, identified in the section on the California Delta will not be repeated here but should be carefully considered.

*Flooding*

The eastern part of the Northern Central Valley contains the foothills of the Sierra Nevada mountain range. The mountainous areas of the state are projected to have less precipitation falling as snow and to be subject to rapid melt events. This will result in extreme, high-flow events and flooding in the Central Valley. Communities should evaluate local floodplains and recognize areas where a small increase in flood height would inundate large areas and potentially threaten structures, infrastructure, agricultural fields, and/or public safety. As the rivers of the region flow toward San Francisco Bay, the land decreases in elevation and is protected by levees, many of which are vulnerable, particularly to seismic events. The threat of flooding due climate-induced increased flows in the California Delta is examined in Part 1 of this document.
Flooding and damage to infrastructure can put large populations at risk (CDPH, 2008), including:

- The elderly and children less than five years of age, who are isolated or dependent on others for evacuation. As an example, Sutter County is one California's counties having a high proportion of elderly living in nursing homes (English et al., 2007).

- Populations that may lack the resources or knowledge to prepare or respond to disaster due to language or economic status, including having access to transportation, which would allow them to escape, at least temporarily, flooding.

Addressing the flood threats in this region may require regional collaboration. This collaboration should include counties, cities, special districts, the California Department of Water Resources (DWR), the California Emergency Management Agency (Cal EMA), the Federal Emergency Management Agency (FEMA), the Central Valley Flood Protection District, and other entities.

*Agriculture*

The Northern Central Valley is one of the largest agricultural producing regions, not only in California, but in the United States. Between climate change impacts on water availability and seasonal temperature regimes, the health of livestock, productivity of trees and crops are likely to be affected.

Agriculture in this region is varied, with rice, nuts (almonds, walnuts, pistachios), and dairy being three of the most predominant products. Others include pears, cattle, wine grapes, chicken, sweet potatoes, and plums.

Each crop is likely to react slightly differently to alteration in seasonal temperature regimes and water availability. Rice is projected to experience a moderate loss in productivity (less than 10 percent; CCCC, 2009). In the case of nut trees, it is the reduction in nighttime cooling that may have the most impact (Luedeling et al., 2011). Jurisdictions reliant on almonds, walnuts, pistachios, or other nuts should specifically evaluate projected changes in daily low temperatures. It is difficult to specifically project the production impact on crops because this relates to many factors in addition to temperature and precipitation, including pest regimes, availability of imported or groundwater irrigation water, and management practices (Luedeling et al, 2011).

As with crops, climate change impacts on dairy cows depend on a variety of factors. For example, the severity of heat stress, which can influence productivity, is influenced by the following factors (Chase, 2006, p.2):

- The actual temperature and humidity
- The length of the heat stress period
- The degree of night cooling that occurs
- Ventilation and air flow
- The size of the cow
- The level of milk production and dry matter intake prior to the heat stress (higher- producing animals will experience greater effects of heat stress)
- Housing – type, ventilation, overcrowding, etc.
- Water availability
- Coat color (lighter color coats absorb less sunlight)

The impact of climate change on agricultural productivity has the potential to alter a community's economic continuity, including its employment base. Communities should work with farm bureaus and other agricultural organizations to understand the challenges faced and to support these organizations and their members as possible. Communities should also consider developing plans that limit the impact of productivity reductions on community operations and the provision of basic services.

*Equity, Health, and Socio-economic Impacts*

Increased temperatures and more frequent heat waves are expected in the region. Sacramento County ranked eighth in the absolute numbers of the elderly and children less than five years of age. These two populations are most likely to suffer from heat-related illnesses and heat events (English et al., 2007). Impervious surfaces are increasing in the Central Valley, increasing the potential impacts of heat islands (English et al., 2007). Farm employment or lodging and food services are among the top five employment sectors in several of the counties in this region. Agricultural workers and employees in the tourist industry are more susceptible to heat events. The foothill areas outside of Sacramento area (e.g., Placerville, Auburn, Grass Valley) show higher ozone levels and increased temperatures. Those most vulnerable to high levels of ozone and particulate matter include people who work or spend a lot of time outdoors, such as residents of this region who are employees of the tourist industry (Lake Tahoe) in the nearby Northern Sierra region. (Medina-Ramon and Schwartz, 2008).

Regardless of their occupation, the poor who are less likely to have the adaptive capacity to prevent and address impacts for reasons stated above. For instance, Merced and Madera counties are considered "high poverty" counties (English et al., 2007). Butte, Stanislaus, Tehama, and Yolo all have poverty levels at approximately 20%. Households eligible for energy utility financial assistance programs are an indicator of potential impacts. These households may be more at risk of not using cooling appliances, such as air conditioning, due to associated energy costs. A relatively high proportion of Yuba County's population (56 to 63 percent) is eligible for energy assistance. Merced and Madera counties have moderately high proportions of populations eligible (47 to 55 percent) (English et al., 2007).

*Water Supply*

Shorter rainfall events and rapid snowmelt will reduce the region's water supply by making water more difficult to capture in reservoirs or retain for groundwater recharge. Recreation and tourism in the region are also likely to suffer due to lower water levels in waterways and reservoirs and declining snowpack.

There also will be impacts upon agriculture due to reduced or altered precipitation. Water supply (for irrigation) can alleviate some of the other climate stresses (altered temperature or precipitation) or, in the case of reduced water supply, exacerbate them. The challenge of climate change is that water supply is projected to be reduced and water that is available will be more costly for users. Employees of water reliant industries such as agriculture may become more economically vulnerable because of unstable working conditions.

*Fire*

Fire risk is projected to increase in the foothills lining the eastern edge of the region. The areas northeast of Sacramento, due to population density and fire risk, are projected to have large property loss (Westerling and Bryant, 2006). Jurisdictions should pay careful attention to the wildland-urban interface and enforcement of mitigation measures such as residential vegetation and setbacks.

**Additional Resources**

- Wildfire Resources
  - California Fire Science Consortium, Central & South Coast Module: http://www.cafiresci.org/home-central-and-southern-ca/
  - California Fire Alliance: http://cafirealliance.org/
  - California FireSafe Council: http://www.firesafecouncil.org/
- Biodiversity and Ecosystems
  - California Department of Fish and Game. 2007. California Wildlife: Conservation Challenges - California's Wildlife Action Plan. Sacramento. Retrieved from www.dfg.ca.gov/habitats/wdp/ The Wildlife Action Plan divides the state into regions. The Central Valley and Bay-Delta Regions overlap with the Northern Central Valley region.

# 7.0 Bay-Delta Region

***Counties***: Contra Costa, Sacramento, San Joaquin, Solano, and Yolo
***Five Largest Cities (CDOF, 2011)***: Sacramento (469,566); Stockton (293,515); Elk Grove (154,594); Vallejo (116,508); Fairfield (104, 815)

| Total 2010 Population | |
|---|---|
| **Bay-Delta Region** | **3,638,618** |
| Contra Costa | 1,049,025 |
| Sacramento | 1,418,788 |
| San Joaquin | 685,306 |
| Solano | 413,344 |
| Yolo | 72,155 |

U.S. Census Bureau, 2010]

The Bay-Delta Region is a unique region in the APG in that it overlaps with two other regions: Bay Area and Northern Central Valley. The choice to include the Bay-Delta as a distinct region is due to the distinct challenges faced by the area and the critical importance it plays in statewide water supply. The content of this region focuses specifically on water management.

The state water system (Central Valley Project and State Water Project) relies on the Delta for water export from the North to the South. In its entirety, the Delta is home to over a half a million people, yet more than 23 million people rely on water that travels through the Delta, and one sixth of all irrigable land in the United States is in the Delta watershed (PPI, 2007).

Prior to the 1850s, the Delta was a vast wetland of channels and islands nourished by semi-annual flooding and sediment deposits. With flood control and land conversion to agriculture, the elevation of large portions of the Delta dropped below sea level. Levees were constructed to protect the agricultural and residential areas, which are now below sea level islands. The lower Delta islands are continuously dropping in elevation, below sea level, because of topsoil loss from agricultural activities, increase in temperatures drying out organic soils, and potential wind storm severity. These factors could result in lower island elevations, increased static levee loading, and higher levee vulnerability.

In the Bay-Delta Region, communities will need to assess vulnerability to the following impacts:

- Temperature increases
- Reduced precipitation
- Sea-level rise
- Flooding – increased flows in areas below sea level, exacerbated by levee failure
- Reduced agricultural productivity
- Reduced water supply
- Public health – heat & air quality
- Decline in Biodiversity - erosion of riparian habitats

## 7.1 Cal-Adapt Projections

Table 17. Summary of Cal-Adapt Climate Projections for the Bay-Delta Region

| Effect | Ranges |
|---|---|
| Temperature Change 1990-2100 | Winter: 6° to 7°F increase in average temperatures<br>Summer: 7° to 9°F increase in average temperatures<br>(Modeled high temperatures – average of all models; high carbon emissions scenario) |
| Precipitation | Precipitation across the region is projected to decline by approximately 3 to 5". The most dramatic decline of 5" is projected around Richmond while most other areas are projected to experience a decline of 4", although Stockton may only experience a 3" decline in precipitation.<br>(CCSM3 climate model; high carbon emissions scenario) |
| Sea Level Rise | The portions of the Delta Region in close proximity of the San Francisco Bay are projected to be increasingly susceptible to 1.4-meter sea level rise. Solano County is anticipated to experience a 13% increase in estimated acreage of land vulnerable to a 100-year flood event. This indicator rises to 40% in Contra Costa County and 59% in Sacramento Count. Most flooding is projected to occur in areas around Suisun City, Pittsburg, Benicia, Richmond, and Vallejo. |
| Wildfire Risk | Portions of western and northern Yolo County, north western Solano, southern Contra Costa and eastern San Joaquin and Sacramento Counties are projected to experience limited increases in potential area burned by wildfire. There are moderately high increases projected for the far eastern areas of San Joaquin County. (GFDL model, high carbon emissions scenario) |

[Public Interest Energy Research (2011). Cal-Adapt. Retrieved from: http://cal-adapt.org]

## 7.2 Water Sources

The largest source of water for the Bay-Delta is the Sacramento River, which is fed by several major tributaries including the Pit River and Feather River, as well as other water bodies within the Sacramento River watershed. In addition to the 21 million acre-feet of water that the Sacramento River discharges to the Bay-Delta, just over 3.9 million acre-feet of water flows into the Delta from the Yolo Bypass, San Joaquin River, and other eastern rivers. Precipitation also adds about another 1 million acre-feet. A large amount of water in the Sacramento River watershed is diverted and used before it reaches the Delta.

Groundwater supplies are continually recharged because flows in the channels and the soft, deep soils of Delta islands. Groundwater levels fluctuate because of droughts, development, delivery of surface waters to the region, and periods of extended wet weather (DWR, 2009, pg. D-14). The water table is relatively shallow and groundwater levels in most basins have declined as a result of agricultural and urban development. For example, the Eastern San Joaquin Subbasin has been in severe overdraft with significant land depressions east of Stockton and Lodi (CA DWR, 2009. Pg. D-14).

## 7.3 Biophysical Characteristics

The Bay-Delta region is a floodplain estuary that connects river to ocean and land to water. It was once a large marshland formed by the Sacramento and San Joaquin rivers but as people began to settle in the area, the marsh was drained and diked for flood control and land conversion to agriculture. More than 90 percent of the marshland has been converted to farms or urban areas. Structures like dams and levees in the Delta have

also been detrimental to the migration of species, such as the Chinook salmon (CA Fish and Game, 2005, pg. 335)

Floodplain estuaries are among the most productive ecosystems on the planet but the Delta has very low levels of primary productivity in the upper surface waters of both the Suisun Marsh and the Delta because of a variety of ecological stressors. (CA Fish and Game, 2005, pg. 335) Wildlife and plant species have been subject to habitat loss, degradation, and fragmentation because of agriculture and urban land development, which has profoundly impacted species' ability to survive. The grizzly bear and gray wolf no longer reside in the Delta, but a population of the tule elk has been established in the Suisun Marsh. The Suisun Marsh is an important wintering and nesting area for waterfowl using the Pacific Flyway (CA DWR, 2009, pg. D-5-6)

The ecosystem functions of the Delta have been significantly impacted and irrevocably changed by introduced, non-native, and invasive species. Introduced species now dominate all habitats in the Delta, including the aquatic weed *Egeria densa*, the water hyacinth, the Asian clam and the overbite clam, and the striped bass and largemouth bass, which are predatory and outcompete the native fish species (CA DWR, 2009, pg. D-5-6).

## 7.4 Regional Entities

- Air Districts: Bay Area Air Quality Management District
- Regional Organizations: San Francisco Bay Conservation and Development Commission, Association of Bay Area Governments; Sacramento Area Council of Governments, San Joaquin Council of Governments

## 7.5 Major Infrastructure and Selected Regional Resources

Table 18. Major infrastructure in the Bay-Delta region.

| Types | Names |
|---|---|
| Airports | International: Sacramento Airport<br>General Aviation: Borges-Clarksbug, Buchanan Field, Byron, Franklin Field, McClellan Airfield, New Jerusalem, Nut Tree, Rancho Murrieta, Rio Vista Municipal, Sacramento Executive, Sacramento Mather, Stockton Metropolitan, Tracy Municipal, University, Yolo County |
| Major Hospitals (number of beds) | Doctors Medical Center (394); St. Joseph's Medical Center of Stockton (359); Sutter Memorial Hospital (348); UC Davis Medical Center (613) |
| Military Facilities | Coast Guard Air Station Sacramento; Defense Distribution Depot San Joaquin; Mather Air Force Base; McClellan Air Force Base; Travis Air Force Base |
| Passenger Rail | Altamont Commuter Express; Amtrak; Bay Area Rapid Transit; Cal-P (Central Pacific); SP West Valley Line; San Joaquin (Union Pacific Railroad); Sacramento Regional Light Rail System; |
| National & State Parks | State: Bidwell-Sacramento S.P.; Caswell Memorial S.P ; Mount Diablo S.P; Sutter Buttes S.P. |
| Ports | Benicia; Pittsburg; Richmond; Sacramento; Stockton; Vista Harbor |
| Power Plants (MW(s))*[i]<br>*Located within the 100-year flood zone for 1.5 m. sea-level rise, capacity .1 or greater | Foster-Wheeler Martinez Cogen L.P; Nove Power Plant (3); Pittsburg (1310); GWF Power Systems L.P.; Solano Cogen (1.45). |

S.P. = State Park; MWs = megawatts

*Located within the 100-year flood zone for 1.5-meter sea level rise

## 7.6 Selected Demographic Data

Table 19. Top Five Employment Sectors in the Bay-Delta Region

| Top 5 Employment Sectors – Bay-Delta Region | | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| **Contra Costa** | Retail Trade | Health Care | Government | Professional & Technical Services | Finance & Insurance |
| **Sacramento** | Government | Health Care | Retail Trade | Professional & Technical Services | Finance & Insurance |
| **San Joaquin** | Government | Health Care | Retail Trade | Manufacturing | Lodging & Food Services |
| **Solano** | Government | Retail Trade | Health Care | Lodging & Food Services | Construction |
| **Yolo** | Government | Retail Trade | Health Care | Professional & Technical Services | Transportation & Warehousing |

[CA REAP, 2011]

Table 20. Selected Demographic Data for the Bay-Delta Region

| | Total 2010 Population | Population <5 years | Percent < 5 years | Population ≥65 years | Percent ≥65 years | Population Below Poverty Level | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Estimated - All Ages | Estimated Percent | Margin of Error |
| **Delta** | **3,767,312** | **261,738** | **6.95%** | **426788** | **11.33%** | **541,446** | | |
| Contra Costa | 1,049,025 | 67,018 | 6.40% | 130438 | 12.40% | 97,544 | 9.3 | 0.9 |
| Sacramento | 1,418,788 | 101,063 | 7.10% | 158551 | 11.20% | 234,470 | 16.7 | 1.1 |
| San Joaquin | 685,306 | 54,228 | 7.90% | 71181 | 10.40% | 128,331 | 19 | 1.5 |
| Solano | 413,344 | 26,852 | 6.50% | 46847 | 11.30% | 49,159 | 12.2 | 1.4 |
| Yolo | 200,849 | 12,577 | 6.30% | 19771 | 9.80% | 31,942 | 16.4 | 2.3 |

[US Census, 2010, General Population and Housing Characteristics & Small Area Income and Poverty Estimates]

## 7.7 Adaptation Policy Considerations

### Setting and History

The California Delta is the center of a vast river network that drains the central valley of California, receiving roughly 80% of the water in the state (Delta Vision, 2008). The Delta is fed by several rivers, the largest being the Sacramento River and the San Joaquin River, in addition to the Mokelumne, American, and Calaveras Rivers. These rivers empty into the low lying basin of the Delta which outlets to the San Francisco Bay and then the Pacific Ocean. The Delta prior to the 1850's was nourished by semi-annual flooding and the accompanying sediment deposits, making it for vast wetlands of channels and islands. As the sediment supply was curtailed through flood control and the land was converted to agriculture, the elevation of large portions of the Delta dropped below sea level making this area prone to more frequent flooding. Levees were constructed to protect the agricultural and residential areas on what are now below sea level islands.

The drop in elevation continues, resulting in a need for increased levee height over the roughly 2000 thousand kilometers of levees that continuously hold back water in the low lying areas. The state water system (Central Valley Project and State Water Project) relies on the Delta as the conduit for water exported from the North to the South. In its entirety, the Delta is home to over a half a million people, yet at the same time half of all California residents (>23 million people) rely on water that travels through the Delta, and one sixth of all irrigable land in the United States is in the Delta watershed (PPI, 2007). The conditions in the Delta have been altered dramatically from it pre-developed state which has endangered many native species and hosted even more non-native species. The Delta is a critical component of the state in terms of water supply, economic viability, and environmental resources.

**Lower Bay-Delta**

Climate change in the lower Bay-Delta may result in the following impacts:

- Exacerbate the drop in elevation of low lying areas due to higher temperatures and increased storm/wind activity.
- Render control of the saltwater front that is artificially held downstream of water export pumps difficult due to changes in the magnitude of precipitation and precipitation/snow melt runoff intensity.
- Not have an appreciable impact on the seismic vulnerability of the lower Delta from sea level rise.

The islands in the lower Delta currently hold back water on a continuous basis (i.e., islands are below sea level) and crest heights target the peak water conditions due to tidal fluctuations from the sea, peak flows from the rivers, or the combination of the two. Levee failures and subsequent island flooding regularly occur (over 160 failures in the last century; DWR, 2009) due to peak water level conditions, as well as in the form of what are called “Sunny Day” failures where there are no adverse loading conditions. The Delta has yet to experience a substantial earthquake in its current configuration.

The seismic behavior of the levees in the Delta is a concern as they have not been designed or tested for such loading conditions and may fail via several different mechanisms (e.g., seismic liquefaction of the foundation or embankment soil, co-seismic deformation of the foundation or embankment soil, or post-seismic reconsolidation of the foundation soil). The scenario that threatens disruption of the State’s water supply is an earthquake that can result in multiple levee failures, flooding the fresh water into the below sea level islands, and allowing salt water intrusion to degrade the water quality thereby shutting down water exports to the South (DWR, 2009). Because the levees in the lower Delta currently hold back water on a continuous basis (in some places upwards of 8 m) incremental increases in sea level or increase in peak flows heights will not have an appreciable impact on the seismic vulnerability. The concern is earthquake loading of the vulnerable levees, not relatively small increases in the static loading from increased water level heights. This also holds true for any other asset or community in the lower Delta residing below mean sea level. Seismic levee integrity and static levee integrity are not necessarily addressing the same failure mechanisms.

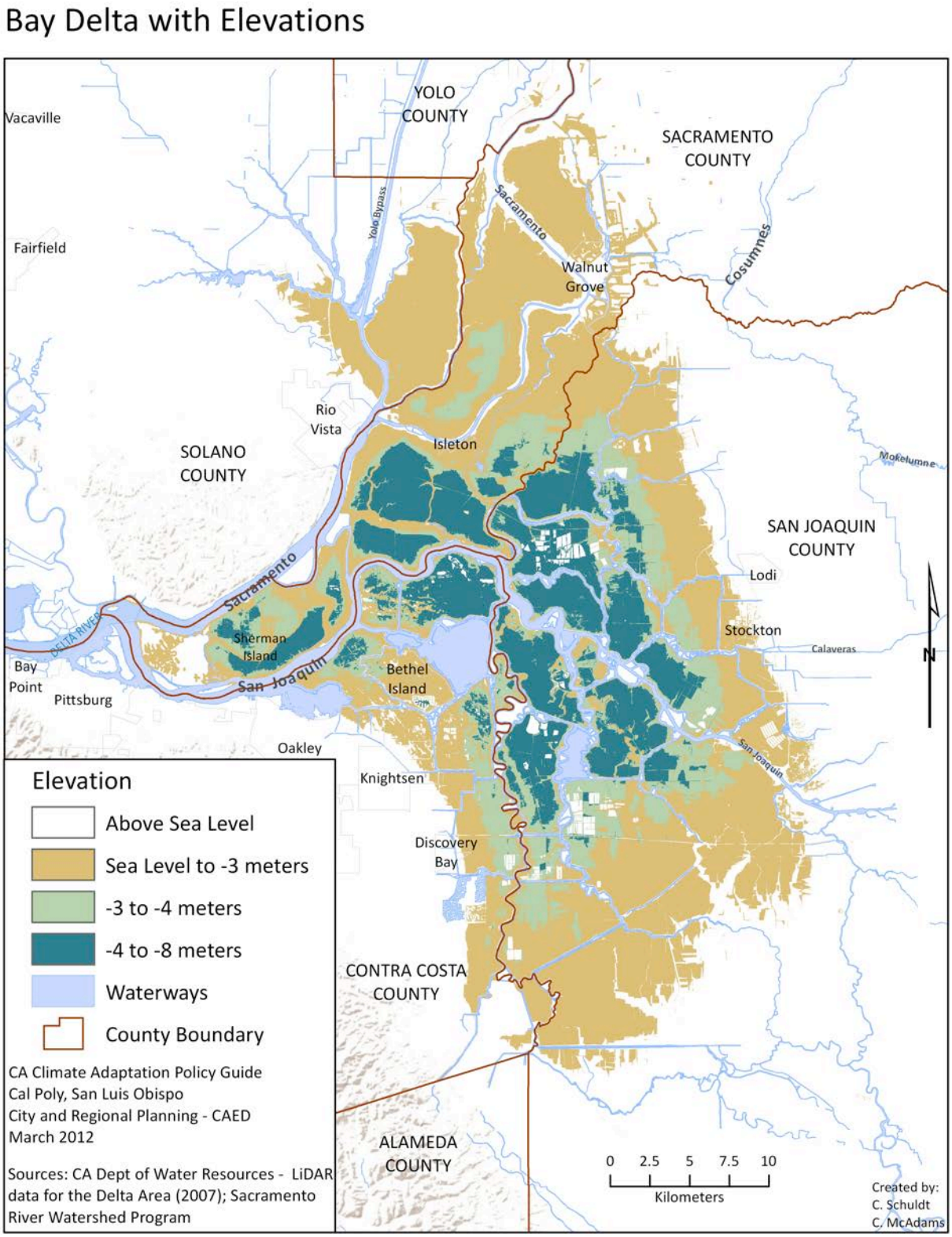



Figure 1. Bay-Delta Region with Elevation

The lower Delta islands are continuously dropping in elevation, below sea level, due to a number of factors. One main factor is the loss of top soil from agricultural activities. An increase in average temperatures accelerating the drying of peaty organic soils and an increase in wind storm severity could exacerbate this process, resulting in lower island elevations, increased static levee loading, and higher levee vulnerability.

Changes in precipitation can have an influence on maintaining the salt water front below the intake pumps for the water delivery to the South. Currently the salt water front is maintained primarily by controlling the release from Shasta Dam, among other flood control structures. Unreliable water supply and timing from the input rivers (Sacramento, Mokolumne, and San Joaquin) due to changes in precipitation and snow melt will make ensuring water quality and water delivery increasing difficult.

**Upper Bay-Delta**

Climate change in the upper Delta is likely to result in the following impacts:

- Increase the static vulnerability of levee failure due to increased precipitation/snowmelt peak runoff.
- Not have an appreciable impact on the seismic vulnerability.

For communities in the upper Delta that are above mean sea level (behind levees that are not continuously holding back water), climate change poses a threat to the static stability of the levees as a function of increased peak flows but will not have an appreciable impact on the seismic vulnerability. The odds of coincidence of higher peak flows with earthquake ground shaking are negligible. However, earthquake ground shaking could damage levees, and if not repaired in time, subsequent peak water levels could result in levee failures. Increase in sea level will affect the static stability of the levees just above current mean sea level and may provide more static push during seismic events, but again the change is insignificant compared to the overall seismic vulnerability of the levees. Again, seismic levee integrity and static levee integrity are not necessarily addressing the same failure mechanisms. Further discussion of flooding is found in the Water Management Supply Sector.

**Climate impacts**

An approach in evaluating levee vulnerability to climate change impacts is to divide adaptation needs into chronic ongoing problems and catastrophic impacts. Ongoing problems address small scale damage and disruption such as property damage, crop loss, or similar that can usually be quantified in terms of insurance claims and can be addressed with maintenance. Catastrophic impacts include the shut-down of the state water exports, disruption of regional or State infrastructure (highways, rail lines, telecommunication and power grids, gas and water mains, etc), or other broad multi-jurisdictional or dramatically disabling impacts which often require more substantial fixes.

Addressing impacts requires close collaboration between local jurisdictions and the levee districts and other flood control or levee management entities. For Delta communities these stakeholders are critical members of the adaptation team who can aid in supplying critical data and providing feedback in understanding risk.

Some of the questions that should be considered when evaluating the current state of preparedness are as follows:

- Have the levees protecting the community and associated resources been assessed for integrity?
- Is there a funding mechanism for ongoing maintenance and repair? Is it adequate for current needs?
- Are levee improvements planned in the near future?
- Is there a monitoring system in place to assess levee integrity?
- Is there a method by which this monitoring is utilized to adjust management practices?
- Is there a local hazard mitigation plan? What are the measures identified for flood mitigation preparation and response?
- Does the urban water management plan include contingency measures in the event of levee breach?

*Structures located in or near flood plain or levee-protected areas*

- Are critical business or community resources located in areas that may be subject to flooding?
- Are there neighborhoods that may face increased flood risk due to climate change?
- Are there some members of particularly vulnerable populations (e.g. elderly) that may be less able to evacuate from vulnerable areas?
- Does local land use policy (e.g. general plan, zoning, or specific plans) allow for expansion of areas considered to be vulnerable to flooding?
- Is there development planned in areas likely to have increasing flood risk (e.g. near levee toe)

*Agricultural productivity*

- Are agricultural facilities and equipment located in areas currently or projected to be at risk for flooding?
- Do local growers have plans for product protection and post flood recovery?

*Public safety*

- Are employees and residents aware of the local flood risk?
- Are employees and residents aware of standard procedures in the event of a flood due to a levee over-topping or failing?
- Are local resources for emergency response and medical care adequately prepared in the event of increased flood risk?

*Infrastructure*

- Do vulnerable regions have evacuation routes identified?
- Are there contingency plans in the event of water, wastewater, energy, or communication networks are interrupted?

**Additional Resources**

- Delta Protection Commission. 2007. DPC Land Use & Resource Management Plan for the Primary Zone of the Delta. Retrieved from http://www.delta.ca.gov/Land%20Use%20and%20Resource%20Management%20Plan%20for%20the%20Prim.htm
- Department of Water Resources. 2011. Delta Risk Management Strategy. Retrieved from http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/

# 8.0 Southern Central Valley Region

***Counties***: Fresno, Kern, Kings, Tulare

***Five Largest Cities (CDOF, 2011)***: Fresno (500,121); Bakersfield (351,443); Visalia (125,770); Clovis (97,218); Tulare (59,926)

| Total 2010 Population | |
|---|---|
| **Southern Central Valley** | **2,365,242** |
| Fresno | 930,450 |
| Kern | 839,631 |
| Kings | 152,982 |
| Tulare | 442,179 |

[U.S. Census Bureau, 2010]

The Southern Central Valley is a largely agricultural, inland region with over 2 million people. Its regional character is defined largely by agriculture, interspersed with cities along primary transport corridors, with Fresno (500,000+ people) prominent in the northern end and Bakersfield (350,000+ people) in the southern end. Agriculture is the predominant economic activity; the region contained the top three agricultural counties in the state in 2010 when evaluated on value, totaling roughly $16 billion California Farm Bureau Federation, 2012). The region also stretches into the foothills of the Sierra Nevada and is known as a prominent tourism access point for Yosemite National Park, Kings Canyon National Park, and Sequoia National Park. Several communities in the region rely on tourism.

Communities in the Southern Central Valley should evaluate vulnerability to the following impacts:

- Temperature increases
- Reduced precipitation
- Reduced Water supply
- Reduced agricultural productivity
- Flooding
- Decrease in tourism – Sierra Nevada foothills
- Wildfire risk in the Sierra Nevada foothills

## 8.1 Cal-Adapt Projections

Table 21. Summary of Cal-Adapt Climate Projections for the Southern Central Valley Region

| Effect | Ranges |
|---|---|
| Temperature Change, 1990-2100 | Winter: Projected increases of 4°F in to 6°F across the region.<br>Summer: Projected increase 7.5°F to 10°F with larger temperature increases in the mountainous regions to the east.<br>(Modeled high temperatures – average of all models; high carbon emissions scenario) |
| Precipitation | Low areas are projected to experience declines in annual precipitation of 3.5 inches, while more elevated areas are projected to experiences loses of approximately 10 inches.<br>(CCSM3 climate model; high carbon emissions scenario) |
| Snowpack | Snowpack in the eastern elevated regions is projected to decrease by approximately 9 inches, resulting in pack that is less than 4 inches by March 2090.<br>(CCSM3 climate model; high carbon emissions scenario) |
| Wildfire Risk | The eastern edge of the region is projected to experience an increase in wildfire risk of 4 to 6 times current conditions.<br>(GFDL model; high emissions scenario) |

[Public Interest Energy Research, 2011. Cal-Adapt. Retrieved from http://cal-adapt.org]

## 8.2 Water Sources

Most of the Southern Central Valley region is located within the Tulare Lake hydrologic region. The water supply in this region is comprised primarily of Sierra snowmelt, delivered by natural waterways and canal systems, and groundwater. During parts of the year, water is limited. As a result, the region has developed a careful management system, integrating groundwater and surface water resources to assure year-round supply (DWR, 2009). This management seeks to avoid groundwater overdraft but has not always succeeded, leading to increased water table depths and associated land subsidence.

Within the region, western areas are subject to more limited resources. Therefore, they rely on imported resources from the Central Valley Project and the State Water Project. These imported sources have increased salt concentrations, which have led to a salt build-up in soils and groundwater.

Agriculture is the largest water user in the region (more than 80 percent), followed by environmental and urban uses. In addition, the extensive network of reservoirs is used for power generation and storage. Reservoir storage capacity in the region totals 2.05 million acre-feet (DWR, 2009).

## 8.3 Biophysical Characteristics

The western portion of the Southern Central Valley is approximately 300 feet above sea level, with the central areas of Fresno and Kings counties lying below an elevation of150 feet. In contrast, the eastern areas of Kern and Tulare counties range from 1800 to 12,000 feet above sea level (CDFG, 2007).

The region features warm, dry summers, with rainfall generally occurring in the winter. Elevations over 5,000 feet receive consistent snowfall. While the western portions of the region are drier than the east, the region contains wetlands, vernal pools, and an extensive network of rivers and associated riparian habitats. Despite having lost the majority of the historic distribution of these habitats, they continue to support an average of 5.5 million waterfowl annually (DWR, 2009). Ecosystems outside urbanized areas accommodate diverse vegetation including irrigated cropland, grassland and a variety of shrub-lands, oak and juniper woodland, and red and white fir forests (DWR, 2011).

## 8.4 Regional Entities

- Air Districts: San Joaquin Valley Unified
- Regional Governments: Fresno Council of Governments, Kings County Association of Governments, Kern Council of Governments, Tulare County Association of Governments
- Tribal Lands (U.S. EPA, 2011): Big Sandy, Cold Springs, Santa Rosa, Tule River

## 8.5 Major Infrastructure and Selected Regional Resources

Table 22. Major Infrastructure in the Southern Central Valley Region

| Types | Names |
|---|---|
| Airports | International: Fresno Yosemite International Airport, Meadows Field International Airport<br>General Aviation: Fresno Chandler Executive Airport, Firebaugh Airport, Mendota Airport, New Coalinga Municipal Airport, Reedley Municipal Airport, Sierra Sky Park Airport, California City Municipal Airport, Delano Municipal Airport, Kern Valley Airport, Lost Hills Airport, Mojave Airport, Shafter Airport, Taft Airport, Tehachapi Municipal Airport, Wasco Airport, Hanford Municipal Airport, Visalia Municipal Airport, Sequoia Field |
| Major Hospitals (number of beds) | Poterville Developmental Center (2,612), Coalinga State Hospital (1,500), Community Regional Medical Center-Fresno (626), St. Agnes Medical Center (436), Bakersfield Memorial Hospital (430), Kaweah Delta Medical Center (403), Good Samaritan Hospital (270), San Joaquin Community Hospital (259), Tulare Regional Medical Center (224), Kern Medical Center (222) |
| Military Facilities | Edwards Air Force Base, China Lake Naval Air Weapons Station, Naval Air Station Lemoore |
| National and State Parks | National: Sequoia National Park, Kings Canyon National Park, Red Rock Canyon National Park, Sequoia National Forest, Sierra National Forest<br>State: Red Rock Canyon State Park |
| Rail | San Joaquin (Union Pacific Railroad), San Joaquin Valley Railroad (Rail America) |

## 8.6 Selected Demographic Data

Table 23. Top Five Employment Sectors in the Southern Central Valley Region

| Employment Sector Ranking | | | | | |
|---|---|---|---|---|---|
| **County** | **1** | **2** | **3** | **4** | **5** |
| **Fresno** | Government | Heath Care | Retail Trade | Forestry & Fishing | Manufacturing |
| **Kern** | Government | Retail Trade | Health Care | Forestry & Fishing | Construction |
| **Kings** | Government | Federal Military | Health Care | Retail Trade | Manufacturing |
| **Tulare** | Government | Retail Trade | Farm Employment | Health Care | Manufacturing |

[CA REAP, 2011]

Table 24. Selected Population Data for the Southern Central Valley Region

| | Total 2010 Population | Population <5 years | Percent < 5 years | Population ≥65 years | Percent ≥65 years | Population Below Poverty Level | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Estimated - All Ages | Estimated Percent | Margin of Error |
| **Southern Central Valley** | **2,365,242** | **205,816** | **8.7%** | **222,667** | **9.4%** | **555,610** | | |
| Fresno | 930,450 | 78,980 | 8.5% | 93,421 | 10.0% | 245,330 | 26.8 | 1.3 |
| Kern | 839,631 | 72,885 | 8.7% | 75,437 | 9.0% | 172,531 | 21.4 | 1.4 |
| Kings | 152,982 | 12,877 | 8.4% | 12,030 | 7.9% | 29,606 | 22.5 | 3.0 |
| Tulare | 442,179 | 41,074 | 9.3% | 41,779 | 9.4% | 108,143 | 24.6 | 2.0 |

[U.S. Census Bureau, 2010, General Population and Housing Characteristics & Small Area Income and Poverty Estimates]

## 8.7 Adaptation Policy Considerations

Climate change impacts in the Southern Central Valley region are varied, but not necessarily new. In many cases, climate is projected to exacerbate existing challenges such as limited water supply, agricultural conditions, social vulnerability, and wildfire.

*Agriculture*

Agriculture in this region is critical to the food supply in California as well as the rest of the country. In 2010, the counties in the Southern Central Valley were ranked first, second, third, and ninth in the state in terms of the economic value of their agricultural production (California Farm Bureau Federation, 2012).

The crops produced are varied and include almonds, milk, cattle, cotton, oranges, and poultry. Each crop type is likely to react differently to alteration in seasonal temperature regimes and changes in water availability. It is difficult to specifically project the production impact on crops because it relates to many factors in addition to temperature and precipitation, including pest regimes, availability of irrigation water, and management practices (Luedeling et al., 2011). The particular aspect of climate change most important to assessing impact also will vary. In the case of nut trees, it the reduction in nighttime cooling that may have most impact (Luedeling et al., 2011). Jurisdictions reliant on almonds, walnuts, pistachios, or other nuts should specifically evaluate projected changes in daily low temperatures.

As with crops, climate change impacts on dairy cows depends on a variety of factors. For example, the severity of heat stress, which can influence productivity, is influenced by the following factors (Chase, 2006, p.2):

- The actual temperature and humidity
- The length of the heat stress period
- The degree of night cooling that occurs
- Ventilation and air flow
- The size of the cow
- The level of milk production and dry matter intake prior to the heat stress (higher- producing animals will experience greater effects of heat stress)
- Housing – type, ventilation, overcrowding, etc.
- Water availability
- Coat color (lighter color coats absorb less sunlight)

The impact of climate change on agricultural productivity has the potential to alter a community's economic continuity, including its employment base. Communities should work with farm bureaus and other agricultural organizations to understand the challenges being faced and support these organizations as possible. Communities should also consider developing plans that limit the impact of productivity reductions on community operations and the provision of basic services.

*Equity, Health, and Socio-economic Impacts*

Heat is a contributing factor in the production of ground level ozone, an air pollutant that affects respiratory function. Visalia is a location in the San Joaquin Valley traditionally high in ozone. Using Visalia and Riverside, two areas traditionally high in ozone, Dreschler et al. (2006) projected that the number of days in California with "conditions conducive to ozone" could increase by 25 to 80 percent by 2100, "depending on warming scenarios" (Kahrl and Roland-Holst, pg. 105)

Inland low-lying areas in California, such as the San Joaquin Valley, reported the greatest number of heat-related deaths in the 2006 heat wave. The counties in the Southern Central Valley region have a relatively large number of agricultural workers. Extreme heat and temperature-related declines in air quality are likely to contribute to increased physical strain, respiratory issues, and general health conditions. Agricultural workers will have increased exposure to heat events and will be especially at risk of heat illness due to the combination of outdoor work and jobs demanding physical exertion. Farm employment is one of the top five industries in Tulare County, and while not registering in the top five employment sectors in the remaining counties, the absolute number of employees involved in agriculture in this region is significant.

Regardless of their occupation, the poor are less likely to have the adaptive capacity to prevent and address impacts. For instance, Fresno County is considered a "high poverty" county (English et. al., 2007). All of the counties in this region exceed poverty levels of greater than 20% of their populations. Households eligible for energy utility financial assistance programs are an indicator of potential impacts. These households may be more at risk of not using cooling appliances, such as air conditioning, due to associated energy costs. Kings and

Tulare counties have moderately high proportions of populations eligible (47 to 55 percent) (English et al., 2007).

The foothill areas outside of and between Fresno and Bakersfield may experience higher ozone levels and temperatures. Those most vulnerable to high levels of ozone and particulate matter include people who work or spend a lot of time outdoors, such residents of this region who are employees of the tourist industry (Sequoia, Kings Canyon, and Yosemite National Parks) in the nearby North Sierra and Southeast Sierra regions.

*Water Supply*

Water supply in this region relies primarily on snowmelt from the Sierra. Climate change is projected to result in a dramatic decrease in snowpack. This change will not only limit the availability of water in the warmer summer months, but also may result in flooding during the spring. Precipitation falling as rain rather than snow and/or in intense rainfall events can limit the ability to capture the water in reservoirs or groundwater.

Further threatening local water supply is the vulnerability of the levees protecting the California Delta. The Delta feeds the State Water Project and Central Valley Project, two key water sources for the region. There is the potential for this source to be compromised by catastrophic levee failure (DWR, 2011). Communities in this region should evaluate their vulnerability to loss of the water supply from the Delta and plan accordingly.

Limited water supply could have drastic impacts on the economic stability of the region. The vast majority of the region's water supply (approximately 80 percent; DWR, 2011) supports agriculture. Loss or reduction of water supply would undermine the economic engine of the region. Communities should carefully plan to bolster water supply, simultaneously working to improve the local efficiency of use.

*Surface Water and Flooding*

Rapid snowmelt or intense rain affects not only water supply, but also the aquatic systems that rely on the flows and the safety of communities in the Sierra foothills. Aquatic systems (e.g., river, lakes, and wetlands) rely on a seasonal hydrological regime. Climate change will disrupt this regime, forcing species to adapt. Recreation and tourism in the region are also likely to suffer due to lower water levels in waterways and reservoirs and declining snowpack. Employees of these industries may become more economically vulnerable because of unstable working conditions.

The mountainous areas are projected to have less precipitation falling as snow and to be subject to rapid melt events. This will result in extreme, high-flow events and flooding in the valley. Communities should evaluate local floodplains and recognize areas where a small increase in flood height would inundate large areas and potentially threaten structures, infrastructure, agricultural fields, and/or public safety.

*Fire*

A big increase in large fire occurrence is projected for the eastern portion of the region. Once burned, these areas may be prone to landslide or debris flow. Large property loss should be expected in areas with higher population densities, such as tourist destinations in the foothills to the east of Fresno.

**Additional Resources**

- Wildfire Resources
  - California Fire Science Consortium, Central & South Coast Module: http://www.cafiresci.org/home-central-and-southern-ca/
  - California Fire Alliance: http://cafirealliance.org/
  - California FireSafe Council: http://www.firesafecouncil.org/
- Biodiversity and Ecosystems
  - California Department of Fish and Game. 2007. California Wildlife: Conservation Challenges - California's Wildlife Action Plan. Sacramento. Retrieved from www.dfg.ca.gov/habitats/wdp/

# 9.0 Central Coast Region

***Counties***: Monterey, San Benito, San Luis Obispo, Santa Barbara, Santa Cruz

***Five Largest Cities (CDOF, 2011)***: Salinas (151,219); Santa Maria (100,062); Santa Barbara (89,253); Santa Cruz (60,800); Watsonville (51,495)

| Total 2010 Population | |
|---|---|
| **Central Coast** | **1,426,240** |
| Monterey | 415,057 |
| San Benito | 55,269 |
| San Luis Obispo | 269,637 |
| Santa Barbara | 423,895 |
| Santa Cruz | 262,382 |

[U.S. Census Bureau, 2010]

The Central Coast region is a largely agricultural, intermittently settled region of over 1 million people, with substantial cities, the largest being Salinas (150,000+ people). Its character is defined by features such as coastal mountains, the Big Sur coastline, wooded hillsides, and the Salinas River Valley. Inland valleys have a somewhat different character from the coastal areas, but agriculture and tourism are common themes on both sides of the coastal ranges.

Communities in the Central Coast region may face one or more of the following climate change impacts:

- Increased temperatures
- Reduced precipitation
- Reduced agricultural productivity
- Sea level rise – coastal flooding and infrastructure damage
- Biodiversity threat
- Public health threats

## 9.1 Cal-Adapt Projections

Table 25. Summary of Cal-Adapt Climate Projections for the Central Coast Region

| Effect | Ranges |
|---|---|
| Temperature Change, 1990-2100 | January: 4.1°F to 5.2°F increase in average temperatures<br>July: 5.1° F to 6°F increase in average temperatures<br>(Modeled high temperatures – average of all models; high carbon emissions scenario) |
| Precipitation | Precipitation varies by location with a general decrease throughout the century. Big Sur's rainfall is projected to decrease by nearly 8 inches in the same timeframe, with 5- to 7-inch decreases in cities like Santa Cruz, San Luis Obispo, and Santa Barbara. Projected decreases in areas of the region that are farther inland are about 4 to 5 inches.<br>(CCSM3 climate model; high carbon emissions scenario) |
| Sea Level Rise | By 2100, sea levels may rise up to 55 inches, posing threats to many areas in the region, particularly the Monterey Bay Area, Morro Bay, Avila Beach, and Santa Barbara. Overall, the estimated increased acreage in each county vulnerable to flooding will be 36 percent in Santa Barbara County, 15 percent in San Luis Obispo County, 12 percent in Santa Cruz County, and 11 percent in Monterey County. |
| Wildfire Risk | There is low to moderate change in projected fire risk in this region save for southwestern Monterey County, near the Big Sur, Carmel Valley, and Greenfield areas, where rates are expected to increase by 70 to 100 percent by 2085 (GFDL climate model; high carbon emissions scenario) |

[Public Interest Energy Research, 2011. Cal-Adapt. Retrieved from http://cal-adapt.org]

## 9.2 Water Sources

Except for the State Water Project, which derives from Sierra Nevada sources, most of the region's water comes from the region itself. Overall, 66 percent of the region's water comes from groundwater, with the remainder split mostly between federal projects and reuse. Only about 6 percent of the region's total, mostly in San Luis Obispo and Santa Barbara counties, comes from the State Water Project (DWR, 2009). Federal projects (the U.S. Bureau of Reclamation's Santa Maria and Cachuma projects) store floodwater from the Santa Maria River watersheds, using it to replenish groundwater and mitigate saltwater intrusion. The region's water supply in 2005 totaled approximately 1.4 million acre-feet, less than 1 percent of which came from outside regions. Agriculture accounted for the majority of use at about 0.9 million acre-feet, followed by urban use at 0.25 million acre-feet. Total reservoir storage capacity in the region is 1.23 million acre-feet (DWR, 2009).

## 9.3 Biophysical Characteristics

The Central Coast region is characterized by the mountains of the Coast Ranges, which surround the Salinas River valley. The Santa Cruz Mountains, the Santa Lucia Range, and the Diablo Range comprise the higher elevation areas, which reach around 5,800 feet on Junipero Serra Peak.

Redwood forests cover much of Santa Cruz County. Scrub and annual grassland comprise most of the coastal vegetation, with annual grasses occupying much of San Benito, San Luis Obispo, Monterey, and Santa Barbara counties. Mixed chaparral is also widespread in the latter three counties along the mountain ranges. Irrigated

cropland makes up most of the land along the Salinas River Valley, along with portions of southern Santa Cruz and northern San Benito counties.

The coastal areas of this region host a variety of critical habitats, from the near-shore ecosystems along Big Sur to bays such as Monterey to the estuaries, including Elkhorn Slough and Morro Bay.

## 9.4 Regional Entities

- Air Districts: Monterey Bay Unified, San Luis Obispo, Santa Barbara
- Regional Organizations: Association of Monterey Bay Area Governments, San Benito Council of Governments, San Luis Obispo Council of Governments, Santa Barbara County Association of Governments, Santa Cruz County Regional Transportation Commission
- Tribal Lands (U.S. EPA, 2011): Santa Ynez

## 9.5 Major Infrastructure and Selected Regional Resources

Table 26. Major Infrastructure in the Central Coast Region

| Types | Names |
|---|---|
| Airports | Bonny Doon Village, Hancock Field, Lompoc, Marina Municipal, McChesney Field, Mesa del Rey, Monterey Peninsula, Paso Robles, Salinas Municipal, Santa Barbara Municipal, Santa Ynez, Watsonville Municipal |
| Major Hospitals (number of beds) | Atascadero State Hospital (3,825), Santa Barbara Cottage Hospital (370), Salinas Valley Memorial Hospital (269), Dominican Hospital-Santa Cruz (268), Marian Medical Center (262), Community Hospital Monterey Peninsula (259), Natividad Medical Center (172), Sierra Vista Regional Medical Center (164), Goleta Valley Cottage Hospital (122), George L. Mee Memorial Hospital (119) |
| Military Facilities | Camp Roberts, Fort Hunter-Leggett, Fort Ord, Presidio of Monterey, U.S. Naval Postgraduate School, Vandenberg Air Force Base |
| National and State Parks | National: Channel Islands National Park, Ellicott Slough National Wildlife Reserve, Elkhorn Slough National Estuarine Sanctuary, Los Padres National Forest, Morro Bay National Estuary, Pinnacles National Monument, Salinas River National Wildlife Refuge<br>State: Andrew Molera S.P.; Big Basin Redwoods S.P.; California Sea Otter State Game Refuge; Castle Rock S.P.; Estero Bluffs S.P.; Forest of Nisene Marks S.P.; Fort Ord Dunes S.P.; Fremont Peak S.P.; Garrapata S.P.; Gaviota S.P.; Harmony Headlands S.P.; Henry Cowell Redwoods S.P.; John Little S.N.R.; Julia Pfieffer Burns S.P.; Limekiln S.P.; Los Osos Oaks S.N.R.; Montana de Oro S.P.; Morro Bay S.P.; Moss Landing State Wildlife Area; Pfeiffer Big Sur S.P.; Point Lobos S.N.R.; San Simeon S.P.; Wilder Ranch S.P. |
| Passenger Rail | Amtrak |

Table 26 (cont'd). Major Infrastructure in the Central Coast Region

| Types | Names |
|---|---|
| Ports | Monterey Fisherman's Wharf, Moss Landing Harbor District, Santa Cruz Harbor |
| Power Plants (MWs)* | Marina Landfill (5.4), Southern California Gas/UCSB (.2), Water Street Jail (.18) |
| Other | UC Santa Cruz, UC Santa Barbara, Cal Poly State University, Cal State Monterey Bay, Alan Hancock College, Cabrillo College, Cuesta College, Hartnell College, Monterey Peninsula College, Santa Barbara City College, Diablo Canyon Power Plant |

S.P. = State Park; S.N.R. = State Natural Reserve; MWs = megawatts

*Located within the 100-year flood zone for 1.5-meter sea level rise, capacity .1 or greater

## 9.6 Selected Demographic Data

Table 27. Top Five Employment Sectors in the Central Coast Region

| Employment Sector Ranking | | | | | |
|---|---|---|---|---|---|
| **County** | **1** | **2** | **3** | **4** | **5** |
| **Monterey** | Government | Lodging & Food Services | Retail Trade | Health Care | Professional & Technical Services |
| **San Benito** | Government | Manufacturing | Retail Trade | Construction | Lodging & Food Services |
| **San Luis Obispo** | Government | Retail Trade | Lodging & Food Services | Health Care | Professional & Technical Services |
| **Santa Barbara** | Government | Retail Trade | Health Care | Professional & Technical Services | Lodging & Food Services |
| **Santa Cruz** | Government | Retail Trade | Health Care | Professional & Technical Services | Construction |

[CA REAP, 2011]

Table 28. Selected Population Data for the Central Coast Region

| | Total 2010 Population | Population <5 years | Percent < 5 years | Population ≥65 years | Percent ≥65 years | Population Below Poverty Level | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Estimated - All Ages | Estimated Percent | Margin of Error |
| **Central Coast** | **1,426,240** | **92,377** | **6.5%** | **174,360** | **12.2%** | **219,506** | | |
| Monterey | 415,057 | 32,547 | 7.8% | 44,422 | 10.7% | 68,031 | 17.1 | 1.7 |
| San Benito | 55,269 | 4,092 | 7.4% | 5,360 | 9.7% | 7,010 | 12.7 | 2.6 |
| San Luis Obispo | 269,637 | 13,343 | 4.9% | 41,022 | 15.2% | 36,179 | 14.3 | 1.7 |
| Santa Barbara | 423,895 | 27,350 | 6.5% | 54,398 | 12.8% | 72,112 | 17.7 | 1.5 |
| Santa Cruz | 262,382 | 15,045 | 5.7% | 29,158 | 11.1% | 36,174 | 14.2 | 2.0 |

[U.S. Census Bureau, 2010, General Population and Housing Characteristics & Small Area Income and Poverty Estimates]

## 9.7 Adaptation Policy Considerations

The Central Coast region is defined primarily by its coastal setting and a temperate climate that makes it an ideal location for agricultural operations such as berries, lettuce, wine grapes, and lettuce (California Farm Bureau Federation, 2012). Climate change will affect coastal conditions and temperatures, as well as fire risk and public health and safety.

*Sea Level Rise*

The region has numerous small communities that depend significantly on tourism. The following areas are likely to see coastal recreation resources such as beaches, wharves, and campgrounds affected by sea level rise: Santa Barbara, Pismo Beach, Morro Bay, Monterey Peninsula, Santa Cruz, and Half Moon Bay. In addition, several large downtowns – including those in Santa Barbara, Monterey, Castroville, and Santa Cruz – lie within areas subject to coastal flooding that will be exacerbated by sea-level rise. A 1.4-meter rise in sea level will increase the population vulnerable to a 100-year coastal storm from 26,070 to 38,000. Most of the population at risk is in Monterey and Santa Cruz counties (CCCC, 2009).

Sea level rise is expected to affect vulnerable populations along the coast through the immediate effects of flooding and temporary displacement and longer-term effects of permanent displacement and disruption of local tourism. Impacts could include temporary and/or permanent displacement, drowning and property damage, and coastal erosion harming recreational activities, tourism, and the tourism industry. Of particular concern are populations that do not have the resources to prepare for, respond to, and recover from disasters. Vulnerable populations living in institutional settings are particularly vulnerable during evacuations from disasters. For instance, Santa Cruz County has high proportion of elderly living in nursing homes that could be affected (English et al., 2007).

Sea level rise also will affect the provision of basic services through disruption of linear infrastructure. Two of the state's major north-south roadways—US 101 and the Pacific Coast Highway (PCH or SR 1)—are located on the coast for portions of their length. Impacts on these roadways could affect regional transportation, access to communities, and access to tourism areas. Weather-related landslides already regularly close SR 1 through Big Sur.

Sea level rise and severe storm surges are a concern for nuclear power plants near the Pacific Ocean, including Diablo Canyon Nuclear Power Plant in San Luis Obispo County. Risks associated with this facility include flooding of containment buildings where highly radioactive spent nuclear fuel is stored and loss of generating capacity owing to severe erosion from the intrusion of seawater and other damages to the facility due to sea level rise. The plant's cooling practices might be affected due to rising ocean temperatures (CDPH, 2008). These impacts could affect those populations living near the facility or reliant on the power produced by the facility.

Finally, communities that depend on groundwater basins within the coastal zone may be affected by saltwater intrusion driven by sea level rise. Of particular concern is the Pajaro Valley, which supplies water for Watsonville and surrounding agricultural areas.

*Ecosystems and Agriculture*

Residential and agricultural development is already having a dramatic impact on some of the endemic species in this region (e.g., through habitat loss). Climate change is projected to further stress these species either through a lack of water (e.g., vernal pools and wetlands) or alteration of habitat conditions (CDFG, 2007). In some cases, species are able to migrate as long as appropriate habitat is available and a pathway to the habitat is unobstructed. In the eastern, warmer, and drier portions of the region, this is a critical consideration for species such as the San Joaquin kit fox (CDFG, 2007).

The ecosystem changes that affect species – including changes in vegetative cover, water availability, seasonal temperature, and precipitation regimes – also affect agricultural. Agriculture plays a significant role in the local economies of the Central Coast region, which produces a large amount of wine grapes, strawberries, lettuce, and vegetable crops (California Farm Bureau Federation, 2012). Climate change has the potential to reduce the productivity of these operations (CAT, 2009). Each crop type has distinct water and temperature needs. As a result, jurisdictions will need to collaborate with agricultural organizations in the region to best support and prepare for impacts.

*Fire*

A slight increase in large fire occurrence is projected for the region (Westerling and Bryant, 2006), with a large increase in the Monterey Bay Area based on shifting vegetative regimes (Westerling et al., 2009). In addition, a large number of home losses is predicted in Monterey due to large fire occurrence in combination with population density (Bryant and Westerling, 2009). Collaboration with air districts will be required for prescribed burning as a fuel reduction tool. The southern subdistrict of Cal Fire's Coastal District (counties of Santa Cruz, Santa Clara, San Mateo, San Francisco, and Marin) may require extra types of regulations beyond normal California Forest Practice Rules.

*Equity, Health, and Socio-economic Impacts*

Lodging and food services are among the top five employment centers in all five counties. Sea level rise may impact the tourism industry and its employees. In addition, workers in these industries which work outside are more susceptible to extreme heat events. Extreme heat events are less likely to occur in the Central Coast region than in California's inland valleys. When they do occur, however, vulnerable populations may be severely affected because of a historic lack of adaptive capacity due to historically milder temperatures.

**Additional Resources**

- Sea Level Rise
  - A notable example of regional cooperation is the effort being led by the Center for Ocean Solutions and Monterey Bay National Marine Sanctuary/NOAA to address sea level rise in the Monterey Bay region: http://www.centerforoceansolutions.org/news-events/press-releases/monterey-bay-communities-convened-prepare-climate-change
- Wildfire
  - California Fire Science Consortium, Central & South Coast Module: http://www.cafiresci.org/home-central-and-southern-ca/
  - California Fire Alliance: http://cafirealliance.org/
- California Department of Fish and Game. 2007. *California Wildlife: Conservation Challenges - California's Wildlife Action Plan*. Sacramento. Retrieved from www.dfg.ca.gov/habitats/wdp/
  The Wildlife Action Plan divides the state into regions. The Central Coast Region defined in the Wildlife Action Plan overlaps with the Central Coast region described in this APG.

# 10.0 North Sierra Region

***Counties*:** Amador, Calaveras, El Dorado, Mariposa, Nevada, Placer, Plumas, Sierra, Tuolumne

***Five Largest Cities (CDOF, 2011)***: Roseville (120,593); Rocklin (57,901); Lincoln (43,248); South Lake Tahoe (21,557); Truckee (16,212)

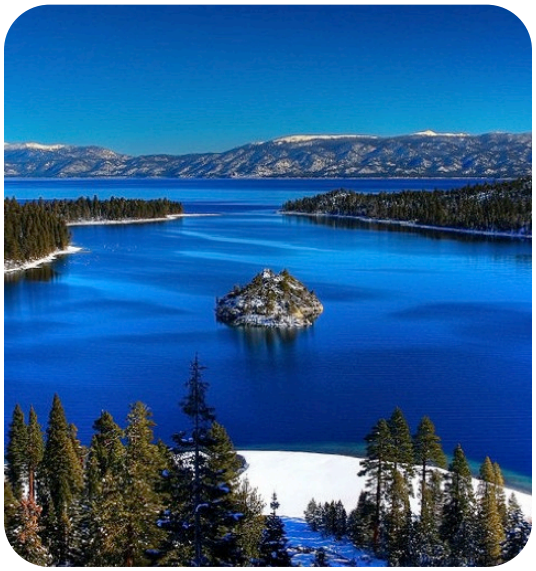
| Total 2010 Population | |
|---|---|
| **North Sierra** | **808,786** |
| Amador | 38,091 |
| Calaveras | 45,578 |
| El Dorado | 181,058 |
| Mariposa | 18,251 |
| Nevada | 98,764 |
| Placer | 348,432 |
| Plumas | 20,007 |
| Sierra | 3,240 |
| Tuolumne | 55,365 |

[U.S. Census Bureau, 2010]

The North Sierra is a mountainous region that is very sparsely settled (808,000+ people), with a few cities scattered along primary transport routes, the largest being Roseville (118,000+) in the foothills near Folsom Dam. Seventy-two percent of the region's residents reside in El Dorado, Nevada, and Placer counties. The most prominent feature is Lake Tahoe and the surrounding summer and winter resorts. Tourism is a primary economic activity; the region contains six of the top seven counties in the state when tourism revenue is measured as a percentage of total earnings (Sierra Business Council, 2007).

Climate change impacts that should be evaluated by communities located in the North Sierra region include the following:

- Increased temperature
- Decreased precipitation
- Reduced snowpack
- Reduced tourism
- Ecosystem change
- Sensitive species stress
- Increased wildfire



## 10.1 Cal-Adapt Projections

Table 29. Summary of Cal-Adapt Climate Projections for the North Sierra Region

| Effect | Ranges |
|---|---|
| Temperature Change, 1990-2100 | January: A 6°F to 7°F increase is projected for the region, with the largest changes being observed in the southern portion of the region.<br>July: Summer temperature may increase nearly 10°F by the end of the century, with the greatest change in the northern part of the region.<br>(Modeled high temperatures – average of all models; high carbon emissions scenario) |
| Precipitation | Precipitation decline is projected throughout the region. The amount of decrease varies from 6 to more than 10 inches, with the larger rainfall reductions projected for the southern portions of the region.<br>(CCSM3 climate model; high carbon emissions scenario) |
| Snowpack | Snowpack levels are projected to decline dramatically in many portions of the region. In southern portions of the region, a decline of nearly 15 inches in snowpack levels – a more than 60-percent drop – is projected by 2090.<br>(CCSM3 climate model; high carbon emissions scenario) |
| Wildfire Risk | Wildfire risk is projected to increase in a range of 1.1 to 10.5 times throughout the region, with the highest risks expected in the northern and southern parts of the region.<br>(GFDL climate model; high carbon emissions scenario) |

[Public Interest Energy Research, 2011. Cal-Adapt. Retrieved from http://cal-adapt.org. Sierra Nevada Alliance, 2010]

## 10.2 Water Sources

The North Sierra climate region primarily overlaps two Department of Water Resources hydrologic regions: Mountain Counties and North Lahontan. The Sierra Nevada snowpack is the major water source for the entire state of California, but local populations rely on local surface and groundwater resources. For example, South Lake Tahoe's primary water supply comes from underground aquifers through wells, and not from Lake Tahoe. Groundwater aquifers are located in areas such as the upper portions of the substantial Feather River watershed (DWR, 2009). Melting of snowpack provides groundwater recharge throughout the Sierra Nevada and valley aquifers. Reservoirs with the largest capacities, over one million acre-feet, depend on water derived from the Sierra Nevada and include the Don Pedro, Lake Almanor, Lake McClure, New Melones, and Oroville reservoirs (DWR, 2009).

## 10.3 Biophysical Characteristics

The elevation of the counties in the North Sierra region range from under ,1000 feet above sea level on the eastern edge of the Central Valley to 14,000 feet above sea level at some of the higher mountain peaks. Major land forms include the canyons in the Sierra Nevada carved by glaciers, such as Yosemite Valley.

Melting snowpack feeds the extensive network of rivers and streams that connect to hundreds of lakes and reservoirs in the region. The major rivers in the Sacramento River hydrologic region include the Feather, Yuba, Bear, and American rivers. The major rivers in the San Joaquin River hydrologic region include the Cosumnes, Mokelumne, Calaveras, Stanislaus, Tuolumne, Merced, Chowchilla, Fresno, and San Joaquin rivers. Most of the

streams and rivers lie on the western slopes because of the pronounced rain shadow effect, leaving desert-like conditions on the other side of the mountain range (DWR, 2009).

With the variation in temperature and elevation, the Sierra Nevada is home to diverse and complex ecosystems. The westernmost edge of the Sierra Nevada along the Central Valley boundary is characterized by woodland and chaparral, where there is high plant biodiversity. The encroachment of human settlements has, however, become a concern at these boundaries. In the lower mountain zone, starting at 3,000 feet, the Ponderosa and Jeffrey pines are characteristic plant forms. With increasing elevation, the mixed conifer zone transitions into an upper mountain zone around 7,000 feet. Generally beginning at 9,500 feet, above the tree line, the alpine zone has limited vegetation because of the harsh climate conditions (UCSNEP, 1996). This region contains more than 3,500 native species of plants, making up more than 50 percent of the plant diversity in California. Vegetation grows along a north-south axis pattern, with the dominant watersheds that flow from east to west contributing to a secondary pattern. Native animal species include the endangered Sierra Nevada red fox, Sierra bighorn sheep, and yellow-legged frog (Sierra Nevada Alliance, 2010).

## 10.4 Regional Entities

- Air Districts: Amador, Calaveras, El Dorado, Mariposa, Northern Sierra, Placer, Tuolumne
- Regional Governments: Amador County Transportation Commission, Calaveras Council of Governments, El Dorado County Transportation Commission, Mariposa County Transportation Commission, Nevada County Transportation Commission, Placer County Transportation Planning Agency, Plumas County Transportation Commission, Sierra County Transportation Commission, Tahoe Metropolitan Planning Organization, Tahoe Regional Planning Agency, Tuolumne County/Cities Area Planning Council
- Tribal Lands (U.S. EPA, 2011): Chicken Ranch, Greenville, Jackson, Sheep Ranch, Shingle Springs, Tuolumne

## 10.5 Major Infrastructure and Selected Regional Resources

Table 30. Major Infrastructure in the North Sierra Region

| Types | Names |
|---|---|
| Airports | International: Lake Tahoe-Reno Airport<br>General Aviation: Truckee-Tahoe, Nevada County, Auburn Municipal, Georgetown, Placerville, Cameron Airpark, Amador County-Westover Field, Calaveras County, Columbia |
| Major Hospitals (number of beds) | Kaiser Hospital Sacramento/Roseville-Eureka (340), Sutter-Roseville Medical Center (313), Sierra Nevada Memorial Hospital (121), Barton Memorial Hospital (117), Marshall Medical Center (105), Sutter Auburn Faith Hospital (86), Tuolumne General Medical Facility (79), Tahoe Forest Hospital (72), Sonora Regional Medical Center-Greenley (72), Sonora Regional Medical Center Unit 6&7 (68) |
| Military Facilities | Sierra Army Depot in Herlong |
| National and State Parks | National: Plumas National Forest, El Dorado National Forest, Stanislaus National Forest, Yosemite National Park, Tahoe National Forest, Sequoia National Forest, Kings Canyon National Park<br>State: Burton Creek S.P.; Calaveras Big Trees S.P.; D.L. Bliss S.P.; Donner Memorial S.P.; Ed Z'berg Sugar Pine Point S.P.; Emerald Bay S.P.; Plumas-Eureka S.P.; South Yuba River S.P.; Tahoe Recreation Area; Washoe Meadows S.P. |

S.P. = State Park

## 10.6 Selected Demographic Data

Table 31. Top Five Employment Sectors in the North Sierra Region

| Employment Sector Ranking | | | | | |
|---|---|---|---|---|---|
| **County** | **1** | **2** | **3** | **4** | **5** |
| Amador | Government | Retail Trade | Health Care | Professional & Technical Services | Construction |
| Calaveras | Government | Construction | Retail Trade | Other Services | Real Estate |
| El Dorado | Government | Professional & Technical Services | Retail Trade | Finance and Insurance | Real Estate |
| Mariposa | Lodging & Food Services | Government | Construction | Other Services | Retail Trade |
| Nevada | Retail Trade | Government | Construction | Health Care | Professional & Technical Services |
| Placer | Retail Trade | Government | Health Care | Lodging & Food Services | Finance & Insurance |
| Plumas | Government | Retail Trade | Construction | Lodging & Food Services | Health Care |
| Sierra | Government | Health Care | Administrative & Waste Services | Professional & Technical Services | Finance & Insurance |
| Tuolumne | Government | Health Care | Retail Trade | Lodging & Food Services | Construction |

[CA REAP, 2011]

Table 32. Selected Population Data for the North Sierra Region

| | Total 2010 Population | Population <5 years | Percent < 5 years | Population ≥65 years | Percent ≥65 years | Population Below Poverty Level | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Estimated - All Ages | Estimated Percent | Margin of Error |
| **North Sierra** | **808,786** | **42,285** | **5.2%** | **136,635** | **16.9%** | **82,876** | | |
| Amador | 38,091 | 1,431 | 3.8% | 7,865 | 20.6% | 4,286 | 12.8 | 2.6 |
| Calaveras | 45,578 | 1,992 | 4.4% | 9,565 | 21.0% | 4,996 | 11.1 | 2.7 |
| El Dorado | 181,058 | 9,513 | 5.3% | 26,524 | 14.6% | 16,825 | 9.4 | 1.6 |
| Mariposa | 18,251 | 775 | 4.2% | 3,821 | 20.9% | 2,665 | 14.8 | 3.0 |
| Nevada | 98,764 | 4,365 | 4.4% | 19,174 | 19.4% | 11,456 | 11.7 | 1.8 |
| Placer | 348,432 | 20,851 | 6.0% | 53,562 | 15.4% | 31,489 | 9.1 | 0.9 |
| Plumas | 20,007 | 883 | 4.4% | 4,154 | 20.8% | 3,012 | 15.3 | 2.7 |
| Sierra | 3,240 | 147 | 4.5% | 676 | 20.9% | 427 | 13.4 | 3.0 |
| Tuolumne | 55,365 | 2,328 | 4.2% | 11,294 | 20.4% | 7,720 | 15.2 | 3.0 |

[U.S. Census Bureau, 2010, General Population and Housing Characteristics & Small Area Income and Poverty Estimates]

## 10.7 Adaptation Policy Considerations

The North Sierra is rich in natural resources. It is the source for the majority of the water used by the state and home to a varied landscape supporting rich biodiversity.

In the past, this region relied on industries such as mining, timber production, and agriculture. Population growth in recent decades has shifted the region's economy to be driven by the provision of services, tourism, and second home development (Sierra Business Council, 2007). Today, the region's economy is primarily tourism-based. Climate change has the potential to disrupt many features that characterize the region, including ecosystem health, snowpack, and the tourist economy.

*Ecosystems and Biodiversity*

One of the biggest threats to the ecosystems of the North Sierra is development pressure, including ski area development, second home development, and agriculture (including timber). While these pressures are not caused by climate change, they interact with the changes in climate to further stress ecosystems and endemic species. Climate change can cause habitats to shift, creating conditions inhospitable to these species (CDFG, 2007). As a result, plant and animal species tend to migrate either up in elevation or farther north. Development can limit opportunities for migration and also introduce non-native species, which can further damage habitat.

Timber practices have also had ecosystem consequences that are exacerbated by climate change. The timber industry has resulted in forests with trees of similar age, lacking snags and underbrush. These management practices reduce the diversity of the habitat. In addition, logging road construction and fire suppression has also altered these habitats (CDFG, 2007).

The most altered habitat in the Sierra is aquatic and riparian systems. The causes of this change include development and water diversion (CDFG, 2007). Changes in hydrologic flow regime and increased temperature will further stress these systems, which are home to many special- status species.

*Snowpack and Flooding*

The North Sierra snowpack serves as a reservoir for the rest of the state. The climate-related decrease in snowpack therefore will have dramatic consequences on the lowland area that depends on this water.

In addition, the snowpack decrease may cause the North Sierra region to experience detrimental impacts from flooding, landslide, and loss of economic base (e.g., skiing). These flood events are likely to put additional pressure on water infrastructure and increase the chance of flooding along waterways. Flooding and damage to infrastructure can put large populations at risk (CDPH, 2008). The populations at risk include the elderly and children, who are isolated or dependent on others for evacuation, and populations that may lack the resources or knowledge to prepare or respond to disaster due to language barriers or economic status, including having access to transportation, which would allow them to escape, at least temporarily, flooding (English et al., 2007).

More than any other part of the state, the North Sierra region relies on tourism as its economic base. Recreation and tourism are also likely to suffer due to lower water levels in waterways and reservoirs and

declining snowpack. Reduced recreational opportunities due to fewer ski days or low water levels will affect the other economic sectors fed by tourism such as hotels, restaurants, and second home development. In addition, employees of these industries may become more economically vulnerable because of unstable working conditions.

*Wildfire*

Despite the fact that the ecosystems in the North Sierra have evolved with recurring fire, there is a long history of fire suppression in the North Sierra region. Recently, fire has been recognized as a critical part of ecosystem function (CDFG, 2007). The challenge is twofold: (1) a century of built-up fuel due to suppression cannot be remedied quickly, and (2) the number of structures that have been built throughout the region make it difficult to let fires burn.

To this mix, climate change is added. Climate change is projected to result in large increases in wildfire frequency and size. The expected property loss is likely to be highest in areas with higher population densities (Westerling and Bryant, 2006).

Fire can also set in motion a series of other potential impacts. Following fire, an intense rainstorm can result in landslide or large erosion events that can have drastic consequences for the receiving stream, river, or lake.

*Equity, Health, and Socio-economic Impacts*

The foothill areas outside the Sacramento area (e.g., Placerville, Auborun, Grass Valley) show higher ozone levels and increased temperatures. People over the age of 65 have the largest increase in mortality with increased concentrations of ozone (Medina-Ramon and Schwartz, 2008), and the elderly make up approximately 20% of the population in Amador, Calaveras, Mariposa, Nevada, Plumas, Sierra, and Tuolomne counties. In addition, people who work or spend a lot of time outdoors, such as employees of the tourist industry (Lake Tahoe), are vulnerable. In Mariposa, Placer, Plumas, Tuolomne counties, Lodging and food services rank among the top five employment sectors. The combination of diminished snowpack and exposure to higher ozone levels may make these populations particularly vulnerable.

**Additional Resources**

- Wildfire Resources
  - California Fire Science Consortium, Sierra Nevada Module: http://www.cafiresci.org/homepage-sierra-nevada/
  - Northern California Prescribed Fire Council: http://thewatershedcenter.farming.officelive.com/PrescribedFire.aspx
  - NorCal Society of American Foresters: http://norcalsaf.org/
  - Quincy Library Group: http://qlg.org/
  - California Fire Alliance: http://cafirealliance.org/
  - California FireSafe Council: http://www.firesafecouncil.org/
- Biodiversity and Ecosystems
  - Sierra Nevada Ecosystem Project: http://ceres.ca.gov/snep/
  - California Department of Fish and Game. 2007. California Wildlife: Conservation Challenges - California's Wildlife Action Plan. Sacramento. Retrieved from www.dfg.ca.gov/habitats/wdp/
    The Wildlife Action Plan divides the state into regions. The Sierra Nevada and Cascades Region overlaps with the North Sierra region.
  - Tahoe Regional Planning Agency: http://www.trpa.org/

# 11.0 Southeast Sierra Region

***Counties***: Alpine, Inyo, Mono
***Cities (CDOF, 2011)***: Mammoth Lakes (8,286); Bishop (3,893)

| Total 2010 Population | |
|---|---|
| **Southeast Sierra** | **33,923** |
| Alpine | 1,175 |
| Inyo | 18,546 |
| Mono | 14,202 |

[U.S. Census Bureau, 2010]

The Southeast Sierra is a combination mountainous and desert region and is the most sparsely settled (34,000+ people) of all the climate regions. A few small towns scattered along Highway 395 are heavily used for tourism access to Las Vegas and Lake Tahoe to the north as well as the Sierra Nevada to the west. The largest settlement is the ski resort town of Mammoth Lakes (8,200+), where the winter population swells with ski season. Tourism is a major economic activity in this region, with 50 percent or more of new home construction in Alpine and Mono counties being second home development. There are also modest agricultural operations in this region.

Communities located in the Southeast Sierra region should consider evaluating the following climate change impacts:

- Increased temperatures
- Reduced precipitation
- Economic impacts – tourism decline
- Substantially reduced snowpack
- Flooding

## 11.1 Cal-Adapt Projections

Table 33. Summary of Cal-Adapt Climate Projections for the Southeast Sierra Region

| Effect | Ranges |
|---|---|
| Temperature Change, 1990-2100 | Winter: A 5°F to 10°F increase in temperature is projected.<br>Summer: Summer temperature is slated to rise 8 to 10 degrees.<br>(Modeled high temperatures – average of all models; high carbon emissions scenario) |
| Precipitation | Potential precipitation decline is between 1.7 and 15.1 inches, but range varies widely depending on location. Some areas receive less than 6 inches annually, with projected reductions bringing totals under 4 inches by 2090. In other areas, total rainfall exceeds 45 inches per year and is projected to decrease by roughly 15 inches by 2090.<br>(CCSM3 climate model; high carbon emissions scenario) |
| Snowpack | Snowpack levels are projected to decline dramatically by 2090 in some areas, with drops of over 50 percent.<br>(CCSM3 climate model; high carbon emissions scenario) |
| Wildfire Risk | By 2085, wildfire risk is projected to increase substantially (up to 19.1 times) over current levels in Alpine County and the northern part of Mono County. The rest of Mono County and all of Inyo County is projected to have a wildfire risk between 1.1 to 4.8 times greater than current levels.<br>(GFDL climate model; high carbon emissions scenario) |

[Public Interest Energy Research, 2011. Cal-Adapt. Retrieved from http://cal-adapt.org. Sierra Nevada Alliance, 2010.]

## 11.2 Water Sources

This climate region occupies the southern portion of the North Lahontan hydrologic region and the Mono and Inyo County portions of the South Lahontan hydrologic region. Groundwater meets over 65 percent of urban, agricultural and environmental water demands in the South Lahontan. Locally developed surface water accounts for 90 percent of water consumption in the region (DWR, 2009). Much of the surface water, however, is not available locally because of water appropriation rights that lay claim to the region's water resources. For example, Inyo County has a joint agreement with the Los Angeles Department of Water and Power for groundwater pumping and surface water management in the Owens Valley. The Owens Valley Basin has an estimated capacity of 30 to 35 million acre-feet (DWR, 2009). Replenishment of the basin comes primarily from percolation of the surrounding mountains' stream flow. Major water bodies include Mono Lake, June Lake, Grant Lake, and Lundy Reservoir (Mono County Community Development Department, Planning Division, 2007).

## 11.3 Biophysical Characteristics

The southeastern part of the Sierra is generally dry and arid, typical of regions affected by the rain shadow along mountain ranges. The Southeast Sierra is the location of the highest point in California – Mount Whitney, at 14,505 feet above sea level – and also the lowest point, at 282 feet below sea level in Death Valley National Park. Both features are in Inyo County. Mono Lake in Mono County supports a distinct ecosystem, while the dry lakebed of Owens Lake in Inyo County is a significant reminder of the critical role of water in the state. Mono Lake is also a prominent stop for migrating birds. Major vegetation in the three counties bordering the desert of Nevada include desert shrub, alkali desert shrub, and bristlecone pines in Inyo County and Jeffrey pine, red firs, and subalpine conifers in Alpine County (FRAP, 1998).

## 11.4 Regional Entities

- Air District: Great Basin Unified
- Regional Organizations: Alpine Local Transportation Commission, Inyo County Transportation Commission, Mono County Transportation Commission
- Tribal Lands (U.S. EPA, 2011): Benton Paiute, Big Pine, Bishop, Bridgeport, Fort Independence, Lone Pine, Washoe (Woodfords Community)

## 11.5 Major Infrastructure and Selected Regional Resources

Table 34. Major Infrastructure in the Southeast Sierra Region

| Types | Names |
|---|---|
| Airports | Primary: Mammoth Yosemite Airport<br>General Aviation: Eastern Sierra Regional, Independence, Lone Pine, Bryant, Lee Vining |
| Major Hospitals (number of beds) | Southern Inyo Hospital (37), Northern Inyo Hospital (25), Mammoth Hospital (17) |
| National and State Parks | National: Death Valley National Park, Inyo National Forest<br>State: Grover Hot Springs State Park, Mono Lake Tufa State Park |

## 11.6 Selected Demographic Data

Table 35. Top Five Employment Sectors in the Southeast Sierra Region

| | Employment Sector Ranking | | | | |
|---|---|---|---|---|---|
| **County** | **1** | **2** | **3** | **4** | **5** |
| **Alpine** | Lodging & Food Services | Government | Arts, Entertainment & Recreation | Construction | Other Services |
| **Inyo** | Government | Lodging & Food Services | Retail Trade | Other Services | Construction |
| **Mono** | Lodging & Food Services | Government | Real Estate | Retail Trade | Construction |

[CA REAP, 2011]

Table 36. Selected Population Data for the Southeast Sierra Region

| | Total 2010 Population | Population <5 years | Percent < 5 years | Population ≥65 years | Percent ≥65 years | Population Below Poverty Level | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Estimated - All Ages | Estimated Percent | Margin of Error |
| **South-east Sierra** | **33,923** | **2,034** | **6.0%** | **5,078** | **15.0%** | **4,261** | | |
| Alpine | 1,175 | 71 | 6.0% | 166 | 14.1% | 196 | 16.9 | 4.0 |
| Inyo | 18,546 | 1,070 | 5.8% | 3,535 | 19.1% | 2,535 | 13.9 | 2.7 |
| Mono | 14,202 | 893 | 6.3% | 1,377 | 9.7% | 1,530 | 10.8 | 2.5 |

[U.S. Census Bureau, 2010, General Population and Housing Characteristics & Small Area Income and Poverty Estimates]

## 11.7 Adaptation Policy Considerations

The sparsely populated Southeast Sierra region is heavily reliant on tourism. All three counties in the Southeast Sierra rank in the top seven in the state for tourism revenue as a percentage of total revenue. Second home construction comprises more than half of all home construction in two of the counties.

Similar to the North Sierra, the Southeast Sierra region serves as a source for water for other areas of the state, specifically Los Angeles.

*Ecosystems and Biodiversity*

This region has an incredibly varied set of ecosystems, from high mountains to arid regions to areas with high rainfall. This diversity means that a large number endemic species are supported in the region. Climate change – from reduced rainfall to increased temperatures to altered hydrologic regimes – will stress these species. In some areas, there is currently very little rainfall. A small decrease or prolonged drought can detrimentally affect species adapted to this setting (CDFG, 2007).

Species stressed by alteration of their preferred habitat may have the ability to migrate. Migration is easiest for terrestrial species; these species will most often move farther north or to a higher elevation. Any number of factors, such as road construction or development, can inhibit migration.

*Snowpack and Flooding*

The Southeast Sierra region is home to mountainous areas that have consistent annual snowpack. Aquatic systems rely on this snowpack, as do those downstream jurisdictions that depend on it for water supply. Increased temperatures can result in precipitation falling as rain instead of snow and in rapid snowmelt events. These events can cause flooding and erosion and ultimately result in reduced water supply. Flood events also put additional pressure on water infrastructure. These impacts increase the chance of flooding along waterways. Flooding and damage to infrastructure can put large populations at risk (CDPH, 2008), particularly the elderly and children less than five years of age, who are isolated or dependent on others for evacuation (English et al., 2007).

The loss of snowpack will also have detrimental economic consequences as it a primary draw for the tourist industry in the region, particular in Mammoth Lakes. Employees of this industry may become more economically vulnerable because of unstable working conditions.

*Equity, Health and Socio-economic Impacts*

Inyo County is one of California's counties with the highest proportion (albeit small total population) of elderly living alone in the state, although the absolute number is relatively smaller than in more urban areas (English et al., 2007). Extreme heat events are less likely to occur in the Southeast Sierra region than in other parts of the state. However, when extreme heat events do occur, vulnerable populations may be severely affected because of a historic lack of adaptive capacity having to do with historically milder temperatures.

Foothill and mountainous communities of this region may be particularly subject to respiratory and heat stress due to a combination of higher ozone levels, higher elevations, historical lack of adaptive capacity, and increasing temperatures in these areas (English et al., 2007; Drechsler et al., 2006). Those most vulnerable to

high levels of ozone and particulate matter include and people who work or spend a lot of time outdoors, such as employees of the tourist industry. Lodging and food services rank among the top five employment sectors in all three counties.

**Additional Resources**

- Wildfire Resources
  - California Fire Science Consortium, Sierra Nevada Module: http://www.cafiresci.org/homepage-sierra-nevada/
  - Northern California Prescribed Fire Council: http://thewatershedcenter.farming.officelive.com/PrescribedFire.aspx
  - SoCal Society of American Foresters: http://norcalsaf.org/
  - California Fire Alliance: http://cafirealliance.org/
  - California FireSafe Council: http://www.firesafecouncil.org/
- Biodiversity and Ecosystems
  - Sierra Nevada Ecosystem Project (http://ceres.ca.gov/snep/
  - California Department of Fish and Game. 2007. California Wildlife: Conservation Challenges - California's Wildlife Action Plan. Sacramento. Retrieved from www.dfg.ca.gov/habitats/wdp/
    The Wildlife Action Plan divides the state into regions. The Sierra Nevada and Cascades and Mojave Desert Regions overlap with the Southeast Sierra region.

# 12.0 South Coast Region

***Counties*:** Los Angeles, Orange, San Diego, Ventura

***Five Largest Cities (CDOF, 2011)***: Los Angeles (3,810,129); San Diego (1,311,882); Long Beach (463,894); Anaheim (341,034); Santa Ana (325,228)

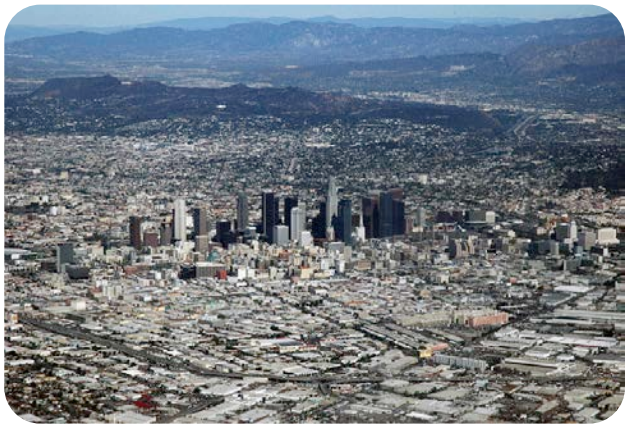
| Total 2010 Population | |
|---|---|
| **South Coast** | **16,747,468** |
| Los Angeles | 9,818,605 |
| Orange | 3,010,232 |
| San Diego | 3,095,313 |
| Ventura | 823,318 |

[U.S. Census Bureau, 2010]

The South Coast (over 16+ million people) is the most heavily urbanized region in the state. The region consists of sprawling suburban development interspersed with dense urban centers, most notably Los Angeles (3.7+ million people) and San Diego (1.3+ million people). The character of the region is defined by the predominant feature of the Southern California coastline, accompanied by the San Gabriel Mountains and coastal mountains to the south. Corners of the region, such as the high desert community of Lancaster, differ substantially in context. However, the most prominent regional feature is the sprawling coastal metropolis along a coastal plain, interspersed with low-lying hills and a few inland areas such as the San Fernando and San Gabriel valleys.

Communities in the South Coast region should consider evaluating the following climate change impacts:

- Increased temperatures
- Reduced precipitation
- Sea level rise
- Economic impacts – tourism, water supply
- Reduced Water supply
- Wildfire risk
- Public health – heat and air quality



## 12.1 Cal-Adapt Projections

Table 37. Summary of Cal-Adapt Climate Projections for the South Coast Region

| Effect | Ranges |
|---|---|
| Temperature Change, 1990-2100 | January: 5°F to 6°F increase in average temperatures.<br>July: 5°F to 6°F increase in average temperatures along the coast and 6°F to 10°F inland.<br>(Modeled high temperatures; high emissions scenario) |
| Precipitation | Annual precipitation will vary by area but decline overall throughout the century. Low-lying coastal areas will lose 3 to 5 inches by 2090, while high elevations will see a drop of 8 to 10 inches. (CCSM3 climate model; high emissions scenario) |
| Sea Level Rise | By 2100, sea levels may rise 55 inches, posing threats to many areas in the region including Venice Beach, the Port of Long Beach, the South Coast naval stations, and San Diego Harbor. As a result of sea level rise, 45 percent more land in Los Angeles County, 40 percent more land in San Diego County, 35 percent more land in Ventura County, and 28 percent more land in Orange County will be vulnerable to 100-year floods. |
| Snowpack | March snowpack in the San Gabriel Mountains will decrease from the 0.7-inch level in 2010 to zero by the end of the century. (CCSM3 climate model; high emissions scenario) |
| Wildfire Risk | Little change is projected in the already high fire risk in this region, save for slight increases expected in a few coastal mountainous areas such as near Ojai and in Castaic, Fallbrook, and Mission Viejo. |

[Public Interest Energy Research, 2011. Cal-Adapt. Retrieved from http://cal-adapt.org]

## 12.2 Water Sources

The South Coast hydrologic region encompasses Ventura, Los Angeles, Orange, and San Diego counties, as well as the southwestern portion of San Bernardino County and western Riverside County. The region derives its water supply primarily from the State Water Project (SWP) (which draws from the Sierra), the Colorado River, groundwater, and local imports. These sources vary in quantity in a given year, but on average the SWP and groundwater provide more than 1.0 million acre-feet each, while the Colorado River provides nearly the same. Depending on the water supply in a given year, approximately 5.0 million acre-feet of water are used. Most of the use is by urban areas at around 4.0 million acre-feet, followed by agriculture, which uses about 0.5 to 1.0 million acre-feet annually. Total reservoir storage capacity is about 3.0 million acre-feet (DWR, 2009).

## 12.3 Biophysical Characteristics

The South Coast region contains several mountain ranges surrounding the coastal basins of the Santa Clara, Los Angeles, and Santa Ana rivers. Elevation ranges from sea level at the coast to around 200 feet for most of the urban areas (State of California, 2005c). The mountain ranges, which peak at about 8,000 feet, are the major physical features of the South Coast counties and include the Sierra Madres, the Transverse Ranges, and the Peninsular Ranges in Ventura, Los Angeles, and San Diego counties, respectively (DWR, 2009). Between the latter two ranges lies the 35mile-by-15-mile Los Angeles Basin, which is almost entirely urbanized. The largest rivers are the Los Angeles, San Diego, San Gabriel, San Luis Rey, Santa Ana, Santa Clara, and Santa Margarita. Due to urbanization, vegetation is constrained to the mountains and consists mostly of scrub and

chaparral. Wildlife includes mountain lions, coyotes, raccoons, golden eagles, ospreys, brown pelicans, kangaroo rats, and foxes (grey and kit) (FRAP, 1998). Marine life includes whales, dolphins, and California sea lions.

## 12.4 Regional Entities

- Air Districts: San Diego, South Coast, Ventura
- Regional Governments: Southern California Association of Governments, San Diego Association of Governments, Los Angeles Metropolitan Transportation Authority, Orange County Transportation Authority, Ventura County Transportation Commission
- Tribal Lands (U.S. EPA, 2011): Barona; Campo, Capitan Grande, Cuyapaipe, Inaja-Cosmit, Jamul Indian Village, La Jolla, La Posta, Los Coyotes, Manzanita, Mesa Grande, Pala, Pauma-Yuima, Rincon, San Pasqual, Santa Ysabel, Sycuan, Table Mountain, Viejas

## 12.5 Major Infrastructure and Selected Regional Resources

Table 38. Major Infrastructure in the South Coast Region

| Types | Names |
|---|---|
| Airports | International: Los Angeles International, San Diego International<br>General Aviation: Bob Hope, Camarillo, El Monte, Fallbrook Community Airpark, John Wayne, Long Beach, Oxnard, Van Nuys, Whiteman |
| Major Hospitals (number of beds) | Lanterman Developmental Center (1,258), Metropolitan State Hospital (1,254), Fairview Developmental Center (1,218), Cedars Sinai Medical Center (958), LA County-USC Medical Center (724), Century City Doctors Hospital (704), Sharp Memorial Hospital (643), Huntington Memorial Hospital (636), Mission Hospital Laguna Beach (621), Scripps Mercy Hospital-Chula Vista (549) |
| Military Facilities | Camp Pendleton Marine Corps Base, El Toro Marine Corps Air Station, Imperial Beach Naval Air Station, Los Alamitos Army Airfield, Los Angeles Air Force Base, March Air Force Base, Marine Corps Air Station Miramar, Marine Corps Recruit Depot San Diego, Naval Base Ventura County/Naval Air Station Point Mugu, North Island Naval Air Station, Point Loma Naval Base, Sea Beach Naval Weapons Station, U.S. Naval Station San Diego (also known as Naval Base San Diego) |
| National and State Parks | National: Angeles National Forest, Cabrillo National Monument, Channel Island National Park, Cleveland National Forest, Los Padres National Forest, Santa Monica Mountains National Recreation Area<br>State: Antelope Valley Poppy Reserve; Arthur Ripley Desert Woodland S.P.; Anza-Borrego Desert S.P.; Border Field S.P.; Chino Hills S.P.; Crystal Cove S.P.; Cuyamaca Rancho S.P.; Leo Carillo S.P.; Malibu Creek S.P.; Palomar Mountain S.P.; Placerita Canyon S.P.; Point Mugu S.P. Ripley Desert Woodland S.P.; Saddleback Butte S.P.; Topanga S.P.; Torrey Pine State Reserve |
| Passenger Rail | Amtrak, Los Angeles County Metro Rail, Metrolink, San Diego County Coaster and Sprinter |

Table 38 (cont'd). Major Infrastructure in the South Coast Region

| Types | Names |
|---|---|
| Ports | Bulk & Container: Port of Hueneme, Port of Long Beach, Port of Los Angeles, Port of San Diego<br>Other: Avalon, Dana Point Harbor, Oceanside Harbor, Redondo Beach Harbor, Two Harbors |
| Power Plants (MWs)* | El Segundo (1,020), Southeast Resource Recovery (34.6), Harbor Cogen (107), Long Beach Peaker (260), Alamitos Generating Station (2,010), Queen Mary (1), Haynes (1,570), Orange County Sanitation District-Plant No. 2 (18), Huntington Beach (904), Goodrich Cogeneration Center Plant (9.5), Eastside Water Renovation (.5), Mandalay (560), Ormond Beach (1,520) |
| Other | San Onofre Nuclear Power Plant<br>Colleges & Universities:<br>*UC:* Irvine, Los Angeles, San Diego<br>*State:* Channel Islands, Dominguez Hills, Fullerton, Long Beach, Los Angeles, Northridge, Pomona, San Diego, San Marcos, and 41 community colleges |

S.P. = State Park; MWs = megawatts

*Located within the 100-year flood zone for 1.5-meter sea level rise

## 12.6 Selected Demographic Data

Table 39. Top Five Employment Sectors in the South Coast Region

| Employment Sector Ranking | | | | | |
|---|---|---|---|---|---|
| **County** | **1** | **2** | **3** | **4** | **5** |
| **Ventura** | Government | Retail Trade | Health Care | Manufacturing | Finance & Insurance |
| **Los Angeles** | Government | Health Care | Retail Trade | Professional & Technical Services | Manufacturing |
| **Orange** | Professional & Technical Services | Retail Trade | Manufacturing | Government | Health Care |
| **San Diego** | Government | Professional & Technical Services | Retail Trade | Health Care | Lodging & Food Services |

[CA REAP, 2011]

Table 40. Selected Population Data for the South Coast Region

| | Total 2010 Population | Population <5 years | Percent < 5 years | Population ≥65 years | Percent ≥65 years | Population Below Poverty Level | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Estimated - All Ages | Estimated Percent | Margin of Error |
| **South Coast** | **16,747,468** | **1,096,243** | **6.5%** | **1,863,110** | **11.1%** | **2,598,624** | | |
| Los Angeles | 9,818,605 | 645,793 | 6.6% | 1,065,699 | 10.9% | 1,699,264 | 17.6 | 0.4 |
| Orange | 3,010,232 | 191,691 | 6.4% | 349,677 | 11.6% | 363,924 | 12.2 | 0.6 |
| San Diego | 3,095,313 | 203,423 | 6.6% | 351,425 | 11.4% | 445,556 | 14.8 | 0.7 |
| Ventura | 823,318 | 55,336 | 6.7% | 96,309 | 11.7% | 89,880 | 11.0 | 1.3 |

[U.S. Census Bureau, 2010, General Population and Housing Characteristics & Small Area Income and Poverty Estimates]

## 12.7 Adaptation Policy Considerations

The South Coast is a highly urbanized region. High population density also creates greater vulnerability to climate-related hazards simply because more people are in harm's way. The concentration of population on the coast has the potential to affect public safety, infrastructure, and the integrity of coastal ecosystems. In addition, the urban setting can also amplify public health risks because increased temperatures are even higher due to the urban heat island.

*Sea Level Rise*

Sea level rise has the potential to result in far-reaching impacts on the South Coast region. Sea level rise may affect region's tourism – the largest value tourist industry in the state (NOEP, 2005) – as well as other considerable assets, including international airports and seaports.

A study by the California Department of Boating and Waterways and San Francisco State University (n.d.) using three example beaches in the region shows considerable loss of recreational and ecological benefits due to sea level rise. A 1.4-meter rise in sea level will increase the population vulnerable to a 100-year coastal storm from 86,000 to 149,300. Most of the population at risk is in Orange County (CCCC, 2007). Areas near Huntington Beach, Seal Beach, the Port of Long Beach, Marina Del Ray, and Port Hueneme also will be of particular concern in the region due to the significant inland penetration of flood waters exacerbated by sea level rise (cal-adapt.org, PIER, 2011).

Sea level rise is expected to affect vulnerable populations along the coast through the immediate effects of flooding and temporary displacement and longer-term effects of permanent displacement and disruption of local tourism. Of particular concern are populations that do not have the resources to prepare for, respond to, and recover from disasters. Impacts could include temporary and/or permanent displacement, drowning and property damage, and coastal erosion harming recreational activities, tourism, and the tourism industry.

Sea level rise and severe storm surges are a concern for nuclear power plants near the Pacific Ocean, including San Onofre Nuclear Power Plant in Orange County. Risks associated with this facility include flooding of containment buildings where highly radioactive spent nuclear fuel is stored, loss of generating capacity owing to severe corrosion from the intrusion of seawater, and other damages to the facility due to sea level rise. The

plant's cooling practices might be impacted due to rising ocean temperatures. (CDPH, 2008) These impacts could affect populations that live near the facility or rely on the power produced by the facility.

Industrial development in the region has left a legacy of brownfields and contaminated waste sites. Some of these will be exposed to coastal flooding due to sea level rise. These sites need to be identified, and priorities for their clean-up may need to be set before contamination spreads.

*Wildfire*

The South Coast already experiences wildfire. The extent to which climate change is projected to alter existing wildfire risk is variable (Westerling and Bryant, 2006). Wildfire frequency and severity will depend on shifts in vegetation and Santa Ana wind behavior (Miller and Schlegal, 2006; Westerling et al., 2009). Management of fire risk such as prescribed burns may be subject to regulations beyond normal California forest practice. For example, the "High Use" subdistricts of Cal Fire's Southern District (counties of Ventura, Santa Barbara, Los Angeles, San Bernardino, Orange, Riverside, Imperial, San Diego, Monterey, San Luis Obispo, and those portions of Placer and El Dorado counties lying within the authority of the Tahoe Regional Planning Agency) may have additional stipulations with regard to management practice.

Increased temperature and decreased moisture, such as longer drought periods, will increase fire vulnerability in a number of areas. Along with impacts associated with temporary and/or permanent displacement, long-term impacts on the elderly and children under the age of five are of concern. Eye and respiratory illnesses due to air pollution resulting from wildfires, and exacerbation of asthma, allergies, chronic obstructive pulmonary disease (COPD), and other cardiovascular diseases are likely to increase.

*Equity, Health, and Socio-economic Impacts*

In the highly populated areas within this region, "urban heat islands" will exacerbate the public health impacts that poor air quality and heat waves have upon the more vulnerable populations of this area. The highest percentages of impervious surfaces are in the urban areas of Los Angeles and San Diego counties, increasing the potential impacts of heat islands (English et al., 2007). Southern California's urban centers are warming more rapidly than other parts of the state (English et al., 2007). Los Angeles, San Diego, and Orange counties rank first, second, and third in the state the absolute numbers of the elderly and children less than five years of age. These two populations are most likely to suffer from heat-related illnesses and heat events (English et al., 2007).

Because of the significant and varied population in this region, there is also likely to be a significant population that fits into a number of the socially vulnerable categories, lacking adaptive capacity. This increases the vulnerability of these populations.

*Water Supply*

Two primary sources of water used by the South Coast region are the State Water Project and the Colorado River. In both cases, these water supplies originate in mountain snowpack. Climate change will result in reduced snowpack, which will translate into reduced water supply. Further threatening the regional water supply is the vulnerability of the levees protecting the California Delta, which feeds the State Water Project (DWR, 2011). Jurisdictions in the South Coast must carefully consider the vulnerability of their water supply.

Climate change will reduce water supply and subsequently increase costs. Industries reliant on water may be affected, resulting in reduced revenue and employment base.

**Additional Resources**

- Sea Level Rise
  - In San Diego, the Public Agency Steering Committee, working with ICLEI-Local Governments for Sustainability and The San Diego Foundation, developed the "Sea Level Rise Adaptation Strategy for San Diego Bay." Source: http://www.cakex.org/sites/default/files/documents/San_Diego_Bay_SLR_Adaptation_Strategy_Complete.pdf. This should serve as a key reference for communities in the region.
- Wildfire
  - California Fire Science Consortium, Central & South Coast Module: http://www.cafiresci.org/home-central-and-southern-ca/
  - SoCal Society of American Foresters: http://norcalsaf.org/
  - Southern California Association of Foresters & Fire Wardens: http://scaffw.org/SCAFFW_home.htm
  - Watershed Fire Council of Southern California: http://watershedfirecouncil.org/home.html
  - California Fire Alliance: http://cafirealliance.org/
  - California FireSafe Council: http://www.firesafecouncil.org/
- Equity, Health, and Socio-economic Impacts
  - The Los Angeles County Department of Health Services' Office of Health Assessment and Epidemiology has produced an excellent resource: *Premature Deaths from Heart Disease and Stroke in Los Angeles County: A Cities and Communities Health Report* (www.lapublichealth.org/epi/docs/CHR_CVH.pdf). Notably, this report provides information on heart disease and stroke, as well as economic hardship, by city or community (spatializing the data to inform built environment policy decisions). (Public Health Law and Policy, How to Create a Healthy General Plan, 2008)
  - Los Angeles and San Diego counties are two of a few places in California with real-time surveillance data for communicable diseases and outbreaks. (CDPH, 2008)

# 13.0 Desert Region

***Counties*:** Imperial, Riverside, San Bernardino

***Five Largest Cities (CDOF, 2011)***: Riverside (305,779); San Bernardino (211,076); Fontana (198,456); Moreno Valley (195,215); Ranch Cucamonga (168,181)

| Total 2010 Population | |
|---|---|
| **Desert** | **4,399,379** |
| Imperial | 174,528 |
| Riverside | 2,189,641 |
| San Bernardino | 2,035,210 |

[U.S. Census Bureau, 2010]

The Desert is a heavily urbanized inland region (4.3± million people) comprised of sprawling suburban development in the west near the South Coast region and vast stretches of open, largely federally owned desert land to the east. Prominent cities within the desert portion include Palm Springs (44,500+) and El Centro (42,500+). The region's character is defined largely by the San Gabriel Mountains, San Gorgonio Mountains, San Jacinto Mountains, and smaller inland mountains reaching through the desert to the Colorado River, which borders the region on the east.

Communities in the Desert region should consider evaluating the following climate change impacts:

- Reduced water supply
- Increased temperature
- Reduced precipitation
- Diminished snowpack
- Wildfire risk
- Public health and social vulnerability
- Stress on special-status species

## 13.1 Cal-Adapt Projections

Table 41. Summary of Cal-Adapt Climate Projections for the Desert Region

| Effect | Ranges |
|---|---|
| Temperature Change, 1990-2100 | January: 5°F to 9°F increase in average temperatures, with 8°F increases in many areas, including in the cities of Riverside and San Bernardino, and a 7° increase at Big Bear.<br>July: 6°F to 10°F increase in average temperatures.<br>(Modeled high temperatures; high emissions scenario) |
| Precipitation | Generally, annual rainfall will decrease in the most populous areas. Wetter areas like the western part of Riverside and southwestern San Bernardino counties will experience a 3.5- to 6-inch decline by the end of the century. Big Bear is expected to lose around 8 inches per year by 2090. Southern Imperial County will have a small decline of about 0.5 inches. The eastern, desert portion of the region will see little to no change in annual rainfall.<br>(CCSM3 climate model; high emissions scenario) |
| Snowpack | March snowpack in the Big Bear area will diminish from the 2.5-inch level of 2010 to 1.4 inches in 2030 and almost zero by 2090.<br>(CCSM3 climate model; high emissions scenario) |
| Wildfire Risk | Most areas are projected to have the same or slightly increased likelihood of wildfire risk. The major exceptions are the Mecca San Gorgonio and San Jacinto Mountains, where wildfire will be 1.5 and 2.0 times more likely.<br>(GFDL climate model; high emissions scenario) |

[Public Interest Energy Research, 2011. Cal-Adapt. Retrieved from http://cal-adapt.org]

## 13.2 Water Sources

Water for most of the Desert region is supplied primarily from the State Water Project, the Colorado River, and local groundwater. The less-populated eastern part of the region uses approximately 4.5 million acre-feet of water annually. Nearly 4 million acre-feet come from the Colorado River, while almost 0.5 million acre-feet are supplied from the State Water Project and groundwater. Usage is split between agriculture, at nearly 4 million acre-feet, and urban consumption, at approximately 0.5 million acre-feet. Storage capacity in the region's reservoirs totals 0.62 million acre-feet (DWR, 2009).

*Note*: The State of California measures water supply/usage for the populous western Riverside County and southwestern San Bernardino County as part of the South Coast hydrologic region, which also includes Los Angeles, San Diego, Orange, and Ventura counties. Please see the South Coast region summary for more information.

## 13.3 Biophysical Characteristics

The Mojave and Colorado deserts dominate the geography of the Desert region. These hot, arid lands lie east of the San Bernardino and San Jacinto mountains.

The Colorado Desert is low-lying, below 1,000 feet in elevation, and is home to desert scrub, palm oasis, and desert wash. Native birds and animals include muskrats, mule deer, coyotes, bobcats, and the Yuma antelope ground squirrel (State of California, 2005a). The Salton Sea, a saltwater lake and the largest lake in California, is situated in the middle of the Colorado Desert. Both northwest and south of the Salton Sea are large agricultural areas irrigated by the Colorado River. The vast majority of the population inhabits the western edge of the region, particularly along the Santa Ana River, in the valley between the San Gabriel, San Bernardino, San Jacinto, and Santa Ana mountains (State of California, 2005a).

By contrast, most of the Mojave region is uninhabited and is owned and managed by the United States Bureau of Land Management. Plant species include desert wash and scrub, alkali and Joshua tree scrub, and palm oasis. Native and rare animals include bighorn sheep, desert tortoise, prairie falcon, and the Mohave ground squirrel. The natural recreational attractions for the region include the Salton Sea, the Picacho State Park along the Colorado River at the Arizona border, and Joshua Tree National Park (State of California, 2009).

## 13.4 Regional Entities

- Air Districts: Imperial, Mojave Desert, South Coast
- Regional Organizations: Imperial Valley Association of Governments, Riverside County Transportation Commission, San Bernardino Associated Governments, San Bernardino County Transportation Commission, Southern California Association of Governments, Western Riverside Council of Governments
- Tribal Lands (U.S. EPA, 2011): Agua Caliente, Augustine, Cabazon, Cahuila, Chemehuevi, Colorado River, Fort Mojave, Morongo, Pechanga, Quechan, Ramona, San Manuel, Santa Rosa, Soboba, Torres-Martinez, Twenty-Nine Palms

## 13.5 Major Infrastructure and Selected Regional Resources

Table 42. Major Infrastructure in the Desert Region

| Types | Names |
|---|---|
| Airports | International: Ontario International<br>General Aviation: Big Bear City; Cable (Upland), Cliff Hatfield Memorial (Calipatria), Corona Municipal, Hesperia, Holtville, Imperial County, Needles, Riverside Municipal |
| Major Hospitals (number of beds) | Patton State Hospital (1,287), Loma-Linda University Medical Center (709), St. Bernadine Medical Center (463), Kaiser Hospital-Fontana (438), Riverside Community Hospital (373), Arrowhead Regional Medical Center (373), Desert Regional Medical Center (367), Riverside County Regional Medical Center (362), Hemet Valley Medical Center (343), Community Hospital of San Bernardino (321) |
| Military Facilities | Edwards Air Force Base, El Centro Naval Air Facility, Fort Irwin, George Air Force Base, Marine Corps Air Ground Combat Center Twentynine Palms, Marine Corps Logistics Base Barstow |
| National and State Parks | National: Joshua Tree National Park, Mojave National Preserve, San Bernardino National Forest, Salton Sea National Wildlife Refuge<br>State: Anza-Borrego Desert State Park, Chino Hills State Park, Mount San Jacinto State Park, Salton Sea State Park |
| Other | Cal State San Bernardino; UC Riverside |

## 13.6 Selected Demographic Data

Table 43. Top Five Employment Sectors in the Desert Region

| | Employment Sector Ranking | | | | |
|---|---|---|---|---|---|
| **County** | **1** | **2** | **3** | **4** | **5** |
| **Imperial** | Government | Retail Trade | Health Care | Lodging & Food Service | Manufacturing |
| **Riverside** | Government | Retail Trade | Health Care | Lodging & Food Service | Construction |
| **San Bernardino** | Government | Retail Trade | Health Care | Lodging & Food Service | Transportation & Warehousing |

[CA REAP, 2011]

Table 44. Selected Population Data for the Desert Region

| | Total 2010 Population | Population <5 years | Percent < 5 years | Population ≥65 years | Percent ≥65 years | Population Below Poverty Level | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Estimated – All Ages | Estimated Percent | Margin of Error |
| **Desert** | **4,399,379** | **334,754** | **7.6%** | **458,086** | **10.4%** | **753,533** | | |
| Imperial | 174,528 | 13,526 | 7.8% | 18,152 | 10.4% | 36,666 | 22.3 | 2.9 |
| Riverside | 2,189,641 | 162,438 | 7.4% | 258,586 | 11.8% | 354,768 | 16.4 | 0.9 |
| San Bernardino | 2,035,210 | 158,790 | 7.8% | 181,348 | 8.9% | 362,099 | 18.1 | 1.1 |

[U.S. Census Bureau, 2010, General Population and Housing Characteristics & Small Area Income and Poverty Estimates]

## 13.7 Adaptation Policy Considerations

The Desert region has a large population along its western edge and smaller populations to the east. The higher population areas are more prone to climate change impacts associated with urban areas (heat and air quality). In the desert areas, climate change will have dramatic impacts on the fragile ecosystems.

*Ecosystems and Biodiversity*

Many of the species endemic to the inland desert areas of California are adapted to a specific, often narrow, temperature and precipitation range. Changes to the seasonal pattern can stress species, particularly aquatic species. Increased temperature and reduced precipitation can limit the existence and extent of habitats such as intermittent streams or other periodic habitats. For terrestrial species, migration becomes a critical point of assessment. Species such as the desert tortoise have had their habitat fragmented and been stressed by invasive species and pest populations (CDFG, 2007).

There are extensive federal land holdings in the region. Preserving species relies partly on managing these lands (for grazing, solar installation, etc and managing the adjoining lands to accommodate migration corridors.

*Water Supply*

Similar to the South Coast region, the Desert region relies on water from the Colorado River and the State Water Project. Both of these sources begin with mountain snowpack. Climate change will result in drastically reduced supply from these sources. Declining snowpack in the San Gabriel Mountains, San Gorgonio Mountains, and San Jacinto Mountains will lead to permanently diminished local water supply.

*Equity, Health, and Socio-economic Impacts*

Riverside and San Bernardino counties rank fourth and seventh in the state in the absolute numbers of the elderly and children less than five years of age. These two populations are most likely to suffer from heat-related illnesses and heat events (English et al., 2007).

Impervious surfaces are increasing in Riverside and San Bernardino counties, increasing the potential impacts of heat islands (English et al., 2007). Foothill and mountainous communities of this region may be particularly subject to respiratory and heat stress due to a combination of higher ozone levels, higher elevations, and increasing temperatures in these areas (English et al., 2007; Drechsler et al., 2006). Those most vulnerable to high levels of ozone and particulate matter include people who work or spend a lot of time outdoors, such as agricultural employees in Imperial County and employees of the tourist industry around Big Bear. As there may be impacts upon tourism from reduced snowpack, employees of this industry may become more economically vulnerable because of unstable working conditions.

Impacts upon safety and emergency response services are of particular concern in this region because of the potential for particularly lengthy and severe heat events. In extreme heat events, roads essential for disaster response could buckle.

*Wildfire*

The high temperatures that characterize much of the desert landscape in this region limit the production of fuels that result in wildfire. However, short periods of high moisture (intense rainfall events) can increase production of fine fuels. In addition, invasive species, particularly in desert settings, may facilitate fire in areas not historically prone to burn.

**Additional Resources**

- Wildfire
  - California Fire Science Consortium, Mojave and Sonoran Desert Module (http://www.cafiresci.org/home-mojave-desert/)
  - California Fire Alliance (http://cafirealliance.org/)
  - California FireSafe Council (http://www.firesafecouncil.org/)
- Biodiversity and Ecosystems
  - California Department of Fish and Game. 2007. California Wildlife: Conservation Challenges - California's Wildlife Action Plan. Sacramento. Retrieved from www.dfg.ca.gov/habitats/wdp/ The Wildlife Action Plan divides the state into regions. The Colorado Desert and Mojave Desert Regions overlap with the Desert region.

# ADAPTATION POLICY GUIDE
# PART 3: ADAPTATION STRATEGIES

Images: California Department of Water Resources

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# Part 3: Adaptation Strategies

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| | |
|---|---|
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# 1.0 Introduction

Part 3 of the APG describes selected adaptation strategies. This part of the APG is not intended to provide a comprehensive listing of policy options. Instead, it seeks to identify strategies that can be implemented on a local level and that can provide ways to address many of the potential impacts described in the preceding sections. Communities can be expected to go beyond the strategies listed below to address all of their high-priority adaptation needs. This may include bolstering programs that are already locally effective or developing innovative strategies based on particular characteristics.

Strategies will require adjustment or greater specificity for application in a community. To aid in the adjustment process, the discussion of each strategy includes a brief description, factors to consider, examples of applications, sources for the strategy itself and/or places to learn more, and possible funding sources, when available.

The strategies are organized by climate impact area (or "sector"). Climate change impacts often interact, however, and as a result some strategies address multiple climate impact areas. Where applicable, the discussion of each strategy notes the overlap with other climate impact areas.

## 2.0 Equity, Health, and Socio-Economic Impacts

The overarching aim should be to improve community planning and design to promote healthy living and to balance integration of social, economic, and environmental concerns. This will require identification of mechanisms to institutionalize the consideration of health and equity in local and regional land use and transportation decision-making in, for example, local general plans, regional transportation plans, or environmental impact mitigation. This integration will result in identification of strategies with co-benefits, ensuring that multiple city needs are met and making efficient use of resources. For example, community design ("smart growth") that promotes walking and bicycling to increase physical activity can also decrease motor vehicle greenhouse gas emissions and other air pollutants.

Adaptation strategies that increase health risks and/or greenhouse gas emissions should be avoided, when possible. An example would be a strategy that promotes air conditioner use to address heat impacts without encouraging changes in electricity production reliance on fossil fuel combustion.

**Strategy 2.1: Establish cooling centers.** On high heat days, provide locations for cooling off for residents who have inadequate insulation and/or do not have access to air conditioning.

**Description:** A cooling center is a place where residents can go to cool off on high heat days. The centers are often located in local government-run facilities such as senior centers or neighborhood parks and recreation sites and are open to all. Typical locations include community centers, fairgrounds, libraries, and other public facilities.

**Factors to Consider:** Establishing cooling centers must be accompanied by plans and resources to identify and provide assistance to individuals requiring transportation to the cooling centers. These centers must also be prepared to accommodate companion animals in order to ensure that vulnerable residents with pets will use the facilities. Cooling strategies for persons exposed to risk of exertional heat illness (those engaged in outdoor work) should also be identified.

**Examples of Applications:**

- Kern County has established cooling centers with "temperature triggers" indicating when they become active: http://www.co.kern.ca.us/pio/coolingcenters.asp. This program was funded through a grant from PG&E.

**Funding Sources:**

- Pacific Gas & Electric. 2012. Cooling Centers. Retrieved from http://www.co.kern.ca.us/pio/coolingcenters.asp

**Strategy 2.2: Develop an urban forest program or plan.** Consider using expansion and improvement of urban forests as part of an adaptation response to reduce the heat island effect.

**Description:** An urban forest program plans for tree planting and long-term maintenance. Increased tree cover in an urban area reduces experience of heat in urban settings. Trees limit the extent to which urban surfaces warm, cool local temperature through evapotranspiration, and provide shade to residents and nearby buildings. As a co-benefit, these programs serve to sequester greenhouse gases and result in more appealing streets.

**Factors to Consider:** To be successful, an urban forest program must be comprehensive. Creating a comprehensive program requires evaluation of existing urban trees, identification of areas in need of tree canopy, and development of a long-term maintenance program.

**Examples of Applications:**

- City of Santa Monica. 2012. Urban Forest Management Plan. Retrieved from http://www.smgov.net/uploadedFiles/Portals/UrbanForest/Handout%206%20-%20Urban%20Forest%20Master%20Plan.pdf
- The City of Portland, OR has a multifaceted urban forestry program including maintenance, oversight, and monitoring: http://www.portlandonline.com/parks/index.cfm?c=38294

**Sources of Information:**

- Keithley, C. and C. Bleier. 2008. An Adaptation Plan for California's Forest Sector and Rangelands p.12. Retrieved from http://www.fire.ca.gov/resource_mgt/resource_mgt_EPRP_Climate/Climate_change_Forestry_Adaptation_strategies_12-11-10.pdf

**Funding Sources:**

- The California Department of Forestry and Fire Protection, Urban and Community Forestry Program lists a series of grants to help support an urban forestry program: http://www.fire.ca.gov/resource_mgt/resource_mgt_urbanforestry.php

**Strategy 2.3: Develop an outreach program specifically targeting vulnerable populations.** Provide vulnerable populations with information on what they need to know about the risks of climate change and what they can do to address them, both individually and at the community level.

**Description:** An outreach program focused on vulnerable populations must identify the populations present in a given community, develop a plan to disseminate the information, and develop materials most appropriate for that population. Perhaps the most important step for a community is to identify dissemination networks (e.g., community-based organizations, local government, philanthropic organizations) that can reach vulnerable populations such as individuals that live alone, the elderly, outdoor workers and their employers, residents in urban heat islands, asthmatics, and immigrants with literacy/language needs.

**Factors to Consider:** Planners should use their contact with the public to assist public health officials and others working with vulnerable populations. Public health officials and non-profits can use their social networks to help inform these communities about changes to the physical environment that will reduce impacts on these communities.

**Examples of Applications:**

- Outreach targeting local health agencies with specific focus on identifying vulnerable populations is included in San Luis Obispo County's EnergyWise Plan (2011; chapter 7): http://www.slocounty.ca.gov/Assets/PL/CAP-LUCE/final/7-SLOCoEWP_Ch7.pdf

**Sources of Information:**

- California Department of Public Health. 2007. Public Health Impacts of Climate Change in California: Community Vulnerability Assessments and Adaptation Strategies. Report No. 1: Heat-Related Illness and Mortality Information for the Public Health Network in California, pp.38-39. http://www.ehib.org/papers/Heat_Vulnerability_2007.pdf
- California Natural Resources Agency. 2009. 2009 California Climate Adaptation Strategy. Retrieved from http://resources.ca.gov/climate_adaptation/docs/Statewide_Adaptation_Strategy.pdf

**Strategy 2.4: Develop an urban heat island reduction program.** Develop a program that coordinates a variety of actions that mitigate the elevated temperatures found in urban areas.

**Description:** Urban heat island mitigation strategies serve to alleviate heat threats by limiting the degree to which the sun can heat an urban environment. The measures included in an urban heat island reduction program focus on increasing vegetation (e.g., through urban forests, vegetative cover, "green" roofs) or increasing the extent to which sunlight is reflected (e.g., through "cool" roofs and "cool" pavement).

**Factors to Consider:** This is a strategy with many co-benefits, but one that must be tailored to local need. Not all strategies that reduce an urban heat island will work equally well in all places. A community will need to evaluate which strategies are most easily implemented, which are likely to be most effective, and which satisfy other local needs.

**Examples of Applications:**

- New York City has developed a plan built on detailed data analysis intended to better understand heat in the urban context and tailor strategies: Columbia University Center for Climate Systems Research and Nasa/Goddard Institute for Space Studies. 2006. Mitigating New York City's Heat Island with Urban Forestry, Living Roofs, and Light Surfaces. Retrieved from http://www.nyserda.ny.gov/en/Publications/Research-and-Development/Environmental/EMEP-Publications/~/media/Files/Publications/Research/Environmental/EMEP/06-06%20Complete%20report-web.ashx

**Sources of Information:**

- United States Environmental Protection Agency. 2011. Urban Heat Island Mitigation. http://www.epa.gov/heatisld/mitigation/index.htm
  This resource provides basic information, example strategies, and public outreach materials.
- United States Environmental Protection Agency. n.d. Reducing Urban Heat Islands: Compendium of Strategies Heat Island Reduction Activities. Retrieved from http://www.epa.gov/heatisld/resources/pdf/ActivitiesCompendium.pdf

**Strategy 2.5: Conduct a communitywide assessment and develop a program to address health vulnerability.** Identify the specific populations and locations with highest vulnerability to climate-related health problems to support development of a multi-faceted program to address needs.

**Description:** This strategy involves identifying and reducing climate-related health vulnerabilities. A communitywide assessment should be conducted to identify vulnerable populations and to assess the modifications required to address needs. For example, communitywide assessments could identify the homes occupied by disabled persons and seniors; assess the safety, energy, and water use efficiency of these homes; and recommend a program for modifying or retrofitting the homes. Retrofits can include weatherproofing, energy-efficient appliances, and shade cover. Identification of urban heat islands should be included in this assessment and could lead to targeted efforts to increase shading through efforts such as expansion of parks and community gardens. As rising temperatures may also increase air pollution, the assessment should consider ways to reduce air pollution in "toxic hot spots" in order to limit health effects.

**Factors to Consider:** Planners need to incorporate health concerns into their public education efforts, assessments, and recommendations regarding both large-scale land use decisions and individual projects. Policies included in general, community, and area plans and regulations included in zoning ordinances can provide planners with the necessary leverage for addressing health issues.

**Examples of Applications:**

- Some communities have turned to mapping technologies to identify vulnerable neighborhoods. Differential exposures to the health-damaging impacts of climate change, such as excessive heat and extreme weather events, can be examined from a geographical equity perspective by using GIS maps overlaid with vulnerability models and current socioeconomic, racial/ethnicity, and cultural group distributions in California.
  *Source:* Morello-Frosch, R. et al. 2009. The Climate Gap: inequities in how climate change hurts Americans & how to close the gap, pp. 22-23. Retrieved from http://dornsife.usc.edu/pere/documents/ClimateGapReport_full_report_web.pdf

**Sources of Information:**

- California Natural Resources Agency. 2009. 2009 California Climate Adaptation Strategy. Retrieved from http://resources.ca.gov/climate_adaptation/docs/Statewide_Adaptation_Strategy.pdf

**Strategy 2.6: Focus planning and intervention programs on neighborhoods that currently experience social or environmental injustice or bear a disproportionate burden of potential public health impacts.**

**Description:** Because specific neighborhoods already experience social and environmental injustice and/or bear a disproportionate burden of public health impacts as a result of these inequities, proactive strategies that address current inequities can build the adaptive capacity of these neighborhoods. Proactive strategies, such as those that address the risks of heat island effects, poor housing quality, and a lack of access to transportation to escape extreme weather events, can also reduce the potential for climate change to result in worsening inequities and public health impacts on the poor and communities of color.

**Factors to Consider:** Environmental and social justice organizations and public health officials are already targeting vulnerable neighborhoods with their own planning and intervention programs. Local agencies should coordinate with organizations and departments on setting priorities for, coordinating, and implementing these efforts.

**Examples of Applications:**

- PolicyLink. (n.d.) Equitable Development Toolkit. Retrieved from http://www.policylink.org/site/c.lkIXLbMNJrE/b.5136575/k.39A1/Equitable_Development_Toolkit.htm

**Sources of Information:**

- Morello-Frosch et al. 2009. The Climate Gap: Inequalities in How Climate Change Hurts Americans and How to Close the Gap. PERE, USC Program for Environmental and Regional Equity. Retrieved from http://dornsife.usc.edu/pere/publications/
- Climate Plan (A coalition of environmental and non-profit planning groups). Social Equity and Affordability: http://www.climateplan.org/resources/social-equity-and-affordability/ Healthy and Safe Communities: http://www.climateplan.org/resources/social-equity-and-affordability/

**Strategy 2.7: Refine emergency preparedness and response to address health impacts.** Update existing emergency preparedness plans and conduct exercises to augment preparedness to better address local health impacts.

**Description:** Local health departments should participate with local emergency managers in refining existing emergency preparedness plans and design and facilitate exercises to augment preparedness for events likely to increase with climate change (e.g., heat waves, wildfires, floods). This effort should also include development of plans for anticipated impacts such as sea level rise and saline intrusion into drinking water. In some cases, this can include an update of existing emergency response plans.

**Factors to Consider:** Preparation also should ensure completeness and availability of identified emergency supplies and resources, including but not limited to items such as water main repair parts, generators, pumps, sandbags, road clearing, medical supplies and services, and communication facilities. The effort should include identifying and cataloging the current supply and procuring additional items and services to ensure preparedness in the event of a climate-related emergency.

**Examples of Applications:**

- City of Santa Cruz. 2011. Climate Adaptation Plan. Retrieved from http://www.cityofsantacruz.com/Modules/ShowDocument.aspx?documentid=23643
- San Luis Obispo County's EnergyWise Plan (2011; chapter 7) includes a policy item for update of the County's Emergency Operations Plan to include health-related events. http://www.slocounty.ca.gov/Assets/PL/CAP-LUCE/final/7-SLOCoEWP_Ch7.pdf

**Sources of Information:**

- California Natural Resources Agency. 2009. 2009 California Climate Adaptation Strategy. Retrieved from http://resources.ca.gov/climate_adaptation/docs/Statewide_Adaptation_Strategy.pdf

**Strategy 2.8: Link climate change adaptation strategies with social equity and public health strategies.** Include social equity and public health as considerations in all adaptation policy development processes.

**Description:** Many strategies to address climate change can be focused or paired with strategies to address existing social equity and public health issues, including those associated with climate change. For example, efforts to link land use with transportation options can be targeted to affordable housing. Measures to address temperature increases, such as urban forests, can be combined with recreational opportunities, such as public parks and pedestrian and bike paths. Measures to increase consumption of local goods and reduce associated transportation needs, such as farmers' markets and community gardens, can be used to address

community development and food security.

**Factors to Consider:** Collaborating with environmental and social justice and public health organizations on climate change strategies opens opportunities for to efficiently addressing social equity and public health impacts, creating multiple benefits and building coalitions around climate change measures.

**Examples of Applications and Sources of Information:**

- Sonoma County Department of Health Services. 2010. Healthy by Design: A Public Health and Land Use Planning Workbook. Retrieved from http://www.healthysonoma.org/javascript/htmleditor/uploads/Healthy_By_Design_Workbook.pdf
- California Department of Public Health. 2012. Climate Action for Health: Integrating Public Health into Climate Action Planning. Retrieved from http://www.cdph.ca.gov/programs/CCDPHP/Documents/CAPS_and_Health_Published3-22-12.pdf

**Strategy 2.9: Use performance metrics and data provided by public health agencies to evaluate and monitor the impacts of climate change strategies on public health.**

**Description:** Public health agencies can assist local planning agencies with the evaluation of proposed and/or implemented climate impact strategies upon public health. According to the California Department of Public Health (2012), data providing a snapshot of the health of local communities are available from more than 35 county and local health departments.

**Examples of Applications:**

- Human Impact Partners. 2011. Elevating Health & Equity into the Sustainable Communities Strategy (SCS) Process. Retrieved from http://www.humanimpact.org/component/jdownloads/finish/16/132/0

**Sources of Information:**

- California Department of Public Health. 2012. Climate Action for Health: Integrating Public Health into Climate Action Planning. Retrieved from http://www.cdph.ca.gov/programs/CCDPHP/Documents/CAPS_and_Health_Published3-22-12.pdf
- Human Impact Partners provides an online source for policy, case studies, and other information focused on integration of health considerations into a variety of planning policies and programs: http://www.humanimpact.org/

## 3. 0 Ocean and Coastal Resources

In the long term, sea level rise needs to be addressed based on local need and context through a variety of policy measures. Part of the aim is to have sea level rise included as a critical consideration when evaluating development proposed near shorelines. The other part of planning for sea level rise is identifying areas for restoration or protection for ecosystem integrity and/or the safety of nearby communities.

**Strategy 3.1: Develop an adaptive management plan to address the long-term impacts of sea level rise.** Include an assessment of local vulnerability, including infrastructure such as roads and water reclamation facilities, buildings in the inundation areas, and ecosystems.

**Description:** An adaptive management plan can provide for flood and erosion protection with consideration for future sea level rise, taking into account 100-year flood events when planning new development and infrastructure projects and/or maintenance and reconstruction of existing projects. This plan should result in identification of areas of priority, suggested strategies, long-term indicators, and integration into other local policy documents (e.g., local hazard mitigation plans).

**Factors to Consider:** These measures are likely to be most successful if efforts are made to coordinate sea level rise protection measures with adjacent jurisdictions to create contiguous shoreline protection. The California Coastal Commission should be involved in this process as well.

**Examples of Applications:**

- The City of San Diego, in collaboration with ICLEI, has begun the adaptive management plan process. A preliminary listing of intended steps can be reviewed here: http://www.icleiusa.org/library/documents/San_Diego_Bay_SLR_Adaptation_Strategy_Exec_Sum.pdf
- The City of Santa Cruz has adopted an adaptation plan that serves as an amendment to its local hazard mitigation plan (LHMP). While this amendment must also be matched with updates of information on other hazards for purposes of FEMA LHMP approval, this adaptation plan reflects a useful example of the type of assessment identified above.
  (City of Santa Cruz. 2011. City of Santa Cruz Climate Adaptation Plan. Retrieved from http://www.cityofsantacruz.com/Modules/ShowDocument.aspx?documentid=23643)

**Sources of Information:**

- Travis, W., and LaClair, J. 2011. Public workshop on key outstanding elements of Bay Plan Amendment no. 1-08 dealing with climate change. San Francisco, CA: San Francisco Bay Conservation and Development Commission. http://www.bcdc.ca.gov/

**Strategy 3.2: Facilitate managed retreat from or upgrade of the most at-risk areas.** Gradually retreat from the most at-risk areas, use these areas differently, or upgrade buildings and other facilities in at-risk areas. Develop plans allowing for coastal inundation in defined areas.

**Description:** Jurisdictions should assess local risk areas based on projected coastal inundation and the importance of facilities, infrastructure, or ecosystems that are at risk. Areas should then be prioritized based on this assessment and action taken. Each development or infrastructure project must be assessed based on how long the action will be adequate given sea level projections.

**Factors to Consider:** When pursuing such development or infrastructure projects, it will be important to determine whether or not to (1) relocate them inland, (2) elevate them above projected sea level rise, or (3) leave them in place and make new or proposed facilities more flood-proof. It will also be important to determine factors such as cost, environmental impacts, funding sources, timing, and compatibility with other plans. These choices should be made in close collaboration with the California Coastal Commission.

**Examples of Applications:**

- A successful example of this strategy is in Ventura, where a bike path at Surfers' Point was recently relocated 65 feet inland using California Coastal Conservancy grant funds. Source: http://articles.latimes.com/2011/jan/16/local/la-me-surfers-point-20110116
- Another example is in Pacifica. The City partnered with the Pacifica Land Trust and the California Coastal Conservancy to purchase two homes and their surrounding acreage. After demolition of

the homes, the dunes were rebuilt and four acres of beach and the nearby estuary were restored. Source: http://coastalmanagement.noaa.gov/initiatives/shoreline_ppr_retreat.html#1

**Sector Overlap:** Biodiversity and Habitat

**Strategy 3.3: Require accounting of sea level rise in all applications for new development in shoreline areas.** Ensure that all applications for new development account for projected sea level rise and provide adequate protection (e.g. setback, armoring).

**Description:** Shoreline areas can include beaches, bluff-tops, and areas along bays or estuaries. Accounting of sea level rise in these areas requires that jurisdictions prepared projected sea level maps to estimate long-term changes in the coastline, bluff erosion rates, and projected coastal flooding. Based on these maps, appropriate setback and/or other appropriate protection can be determined. For consistency, consideration of sea level rise should be included in project review guidelines, integrated into Local Coastal Plans, and reviewed as part of California Environmental Quality Act (CEQA) evaluation.

**Factors to Consider:** Collaboration among adjoining jurisdictions will foster more comprehensive shoreline protection. The implementation of this strategy will also require staff and community education about sea level rise, inherent risks, and available options for addressing the risk.

**Examples of Applications:**

- The San Francisco Bay Conservation and Development Commission (BCDC) Bay Plan Amendment No. 1-08 requires mapping and accounting of sea level rise impacts in land use and management decisions. http://www.bcdc.ca.gov/proposed_bay_plan/10-01Resolution.pdf
- Sea Level Rise Planning Maps is a clearinghouse site that houses sea level rise maps and evaluation for 13 East Coast states. This is a good example of the type of mapping and evaluation that can support this strategy. Cal-Adapt provides a base but will require local evaluation of land use policy, projected growth, and ecosystem vulnerability. http://plan.risingsea.net/index.html
- San Luis Obispo County. 2011. EnergyWise Plan. Chapter 7. Retrieved from http://www.slocounty.ca.gov/Assets/PL/CAP-LUCE/final/7-SLOCoEWP_Ch7.pdf

**Strategy 3.4: Preserve undeveloped and vulnerable shoreline.** In shoreline areas, preserve undeveloped land to support ecosystem adaptation in areas where sea level rise may cause inland migration of species and habitat.

**Description:** Undeveloped shorelines area, particularly along bays or estuaries, should be evaluated for ecological value, vulnerability, and role in local flood protection. Protection and restoration of these areas should be pursued to provide flood protection and habitat and species migration. Tools that can be used to facilitate this protection can include several that are familiar to local jurisdictions, including land use designations (e.g., zoning), building setbacks, consideration during project review, easement acquisition, and habitat conservation plans in situations where special-status species are present.

**Factors to Consider:** Local government land use and tax policies should be evaluated to avoid development on restorable habitat that is critical to ensuring ecosystems resilient to the impacts of climate change. Action such as land preservation can be coordinated with local land conservation and wildlife organizations. The California Coastal Commission should also be consulted. These actions do not need to strictly prohibit development. Instead, shoreline areas should be carefully evaluated. In some cases, development can be managed to allow for future ecosystem resilience.

**Examples of Applications:**

- Similar strategies have been identified for the Bay Area:
  - BCDC. 2011. Revised Staff Report and Staff Recommendation for Proposed Bay Plan Amendment 1-08bConcerning Climate Change. Retrieved from http://www.bcdc.ca.gov/proposed_bay_plan/10-01Recom.pdf
  - Travis, W., and J. LaClair. 2011. Public workshop on key outstanding elements of Bay Plan Amendment no. 1-08 dealing with climate change. San Francisco, CA: San Francisco Bay Conservation and Development Commission. http://www.bcdc.ca.gov/
- The Puget Sound region in Washington State is pursuing similar policies:
  - State of Washington Department of Ecology. 2011. Shoreline Master Program (SMP) Handbook, Appendix A. Retrieved from http://www.ecy.wa.gov/programs/sea/shorelines/smp/handbook/sea_level_guidance.pdf

**Sources of Information:**

- Travis, W., and J. LaClair. 2011. Public workshop on key outstanding elements of Bay Plan Amendment no. 1-08 dealing with climate change. San Francisco, CA: San Francisco Bay Conservation and Development Commission. http://www.bcdc.ca.gov/

**Sector Overlap:** Water Management, Biodiversity and Habitat

**Strategy 3.5: Use transfer of development rights for the rebuilding of structures damaged or destroyed due to flooding in high-risk areas.** Designate areas for increased density in a community, allowing land owners in the high-risk areas to sell their development rights.

**Description:** Transfer of development rights (TDR) is often used to preserve agricultural lands or undeveloped areas. In this case, the same approach would be used transfer the development rights of a high-risk property to a lower-risk property. The advantage is that the land owner in the high-risk area is compensated for the loss of development and a flood-prone area is set aside, decreasing flood risk for the whole community.

**Factors to Consider:** Often the most controversial aspect of TDR programs is selection of the receiving areas that will see an increase in development density. Community acceptance of this density increase requires that the program be accompanied by public education and outreach. Local land trusts can also be a valuable collaborator in developing the program, particularly restricting redevelopment of the high-risk area.

**Examples of Applications:**

- Monterey Bay. 2011. Adaptation in Action: Examples from the Field. Retrieved from http://www.climatechangemontereybay.org/solutions_adaptation.shtml#endnotes
- San Luis Obispo County. 2011. EnergyWise Plan. Retrieved from http://www.slocounty.ca.gov/Assets/PL/CAP-LUCE/final/SLOCoCAP_Board_Approved-Complete+Doc.pdf

**Sources of Information:**

- Grannis, J. 2011. Adaptation Tool Kit: Sea-Level Rise and Coastal Land Use: How Governments Can Use Land-Use Practices to Adapt to Sea-Level Rise. Retrieved from http://www.georgetownclimate.org/sites/default/files/Adaptation_Tool_Kit_SLR.pdf
- Titus, J. 2011. Rolling Easements. Retrieved from ww.epa.gov/cre/downloads/rollingeasementsprimer.pdf

**Sector Overlap:** Water Management, Biodiversity and Habitat

## 4.0 Water Management

This sector focuses on strategies that address climate change impacts on water, including surface water systems, groundwater, flooding, drought, and water supply. The strategies listed below seek to limit community exposure to threats such as flooding or landslide. This can be done through land use policy (zoning, general plans, etc.) or through update of local plans.

Water supply impacts due to reduced snowpack, intense storms, reduced precipitation, or drought can be addressed through promotion of efficient water use, which is often included in urban water management plans and climate plans focused on greenhouse gas reduction. Selected measures to reduce local water use are identified below. These measures and others are now required for California jurisdictions. Senate Bill X7-7 (2009) requires a 20-percent reduction in urban per capita water use in California by 2020. Measures that focus on personal water use and efficiency are not covered in the following list because there are many sources for this information, including the following:

- California Air Pollution Control Officers Associations. 2010. Quantifying Greenhouse Gas Mitigation Measures. Retrieved from: http://www.capcoa.org/wp-content/uploads/2012/03/CAPCOA-ModelPolicies-6-12-09-915am.pdf
- Environmental Protection Agency. 1998. Water Conservation Guidelines. Retrieved from http://www.epa.gov/WaterSense/pubs/guide.html

**Strategy 4.1: Develop coordinated plans for mitigating future flood, landslide, and related impacts through concurrent adoption of updated general plan safety elements and local hazard mitigation plans.** Both in fully built-out communities and growing communities, evaluate projected risks of flooding, landslides, and related hazards. Determine long- and near-term action plan priorities to reduce potential losses. Identify hazard mitigation projects to include in the five-year capital program.

**Description:** This strategy involves updating the general plan safety element, and, where applicable, the local hazard mitigation plan to reduce potential losses of life and property from existing and increased flooding and landslide risks. California law requires each city and county to prepare a general plan, including a safety element that identifies local hazards, such as flooding and landslides. The safety element sets forth goals, objectives, policies, and programs for reducing risk, vulnerability, and losses related to hazards. Federal disaster law requires preparation of local hazard mitigation plans as a precondition for mitigation grant eligibility.

**Factors to Consider:** All of California's cities and counties have adopted general plan safety elements but many of these are not up-to-date. New knowledge has become available since their adoption, both as a result of disaster experiences as well as the federal law requirement for local hazard mitigation planning as a precondition for receiving mitigation grants. Federal regulations emphasize setting priorities for risks and actions to mitigate hazards, adding a useful dimension to general plan safety elements. California law now provides for state financial incentives for adoption of a local hazard mitigation plan as part of the safety element. Concurrent updating and adoption of safety elements and local hazard mitigation plans provides for greater disaster loss avoidance and places communities in stronger positions financially.
Examples of Applications: According to the 2010 California Multi-Hazard Mitigation Plan, 324 of California's 482 cities, or 67 percent, and 37 of its 58 counties, or 64 percent, had Federal Emergency Management

Agency (FEMA)-approved locally adopted hazard mitigation plans as of December 2009. Local hazard mitigation plans for cities and counties covered 31,030,978 people, or 81 percent of the state's population. Compared to 2007, this represented a 34-percent increase in number of cities, a 23-percent increase in number of counties, and a 17-percent increase in total population covered. However, since most of these local hazard mitigation plans were adopted separately from safety elements, the challenge of integrating and strengthening mitigation planning through concurrent adoption remains.

**Sources of Information:**

- Cal EMA. 2010 California Multi-Hazard Mitigation Plan. http://hazardmitigation.calema.ca.gov/docs/2010_SHMP_Final.pdf
- Governor's Office of Planning and Research. 2003. General Plan Guidelines. http://cnps.org/cnps/conservation/conference/2006/General_Plan_Guidelines_Overview%202003.pdf
- Cal EMA. Hazard Mitigation Web Portal. http://hazardmitigation.calema.ca.gov/

**Strategy 4.2: Implement Assembly Bill 162 (2007) requiring flood hazard information in local general plans.** Amend city and county general plan land use, housing, safety, and conservation elements to address new flood hazard and water resource information requirements.

**Description:** AB 162 expands consideration of flood risk in local land use planning throughout California. The recent legislation requires cities and counties to amend local general plans in several very specific ways, including requirements to:

- Identify and annually review new mapping of areas subject to flooding as part of the land use element; and
- Amend housing, safety, and conservation elements to take into account specific flood risk and water management information and issues.

While some of the requirements of AB 162 apply statewide, other provisions apply to lands within the Central Valley. The California Department of Water Resources (DWR) has prepared a guidance document describing the new requirements affecting local planning responsibilities such as general plans, zoning ordinances, development agreements, tentative subdivision maps, and other actions.

**Factors to Consider:** In addition to FEMA's Flood Insurance Rate Maps that show areas within 100-year floodplains (1 percent annual occurrence risk), local general plans must now include reference to a new series of 200-year (0.5 percent annual occurrence risk) flood hazard maps, which DWR is preparing for the Central Valley and other parts of California. This recent legislative initiative has been in effect since 2009.

**Examples of Applications:**

- The requirement for evaluating 200-year flood hazards is being implemented in the Central Valley Flood Protection District in 2012 (see Strategy 3.3.6).

**Sources of Information:**

- Cal EMA. 2010 California Multi-Hazard Mitigation Plan. http://hazardmitigation.calema.ca.gov/docs/2010_SHMP_Final.pdf
- DWR. "Implementing California Flood Legislation into Local Land Use Planning: A Handbook for Local Communities." http://www.water.ca.gov/floodmgmt/lrafmo/fmb/docs/Oct2010_DWR_Handbook_web.pdf

**Strategy 4.3: Implement National Flood Insurance Program (NFIP) activities to minimize and avoid development in flood hazard areas.** Under the National Flood Insurance Act of 1968 participate in national programs geared to reducing flood exposure and covering flood losses through private insurance.

**Description:** Local jurisdictions should use Federal Insurance Rate Map (FIRM) data for the 100-year floodplain (1 percent annual recurrence risk) as a source for determining general plan policies and zoning patterns. Local jurisdictions should also participate in the Community Rating Service system, which reduces rates for flood insurance purchasers. Flood-prone Severe Repetitive Loss communities should pursue flood mitigation assistance grants designed to reduce flood exposure. Jurisdictions should use federal mitigation grant funds to purchase flood threatened or damaged property and raise elevations of homes and key infrastructure facilities.

**Factors to Consider:** Together with other examples below, these practices represent a powerful combination of tools to strengthen natural hazard mitigation in the course of day-to-day development planning. When applying them, however, communities should consider factors such as cost, environmental impacts, funding sources, timing, and private property rights.

**Examples of Applications:**

- Federal grants under the Hazard Mitigation Grant Program of the Stafford Act (1988) and Flood Mitigation Assistance grant program of NFIP for flood mitigation activities by communities with FEMA-approved local hazard mitigation plans.

**Sources of Information:**

- Cal EMA. 2010 California Multi-Hazard Mitigation Plan. http://hazardmitigation.calema.ca.gov/docs/2010_SHMP_Final.pdf

**Strategy 4.4: Restore existing flood control and riparian corridors.** Develop projects that mitigate riverine flooding, improve surface retention and subsurface water storage, and enhance timing of water delivery through restoration of waterways to more natural states.

**Description:** Jurisdictions should evaluate flooding potential, monitor and improve natural conditions to improve flood flow, reduce erosion, improve habitat, and protect adjacent neighborhoods. Jurisdictions should provide for flood and erosion protection with consideration for 100-year flood events, taking into account existing flood management deficiencies and potential increase in flows from climate change, when planning new development and infrastructure projects and/or maintenance and reconstruction of existing projects. Where possible, jurisdictions should convert concrete-lined channels to soft-bottomed waterways, install landscaping on embankments to slow floodwaters, provide natural planting to encourage bio-diversity, and build retention basins for percolation into aquifers. Additional benefits include expansion of active recreation.

**Factors to Consider:** When pursuing such projects, communities should determine factors such as cost, environmental impacts, funding sources, timing, and compatibility with other plans.

**Examples of Applications:**

- A highly prominent example of this strategy representing an ambitious undertaking is restoration of the Los Angeles River: http://lariver.org/

**Sources of Information:**

- Cal EMA. 2010 California Multi-Hazard Mitigation Plan. http://hazardmitigation.calema.ca.gov/docs/2010_SHMP_Final.pdf

**Funding Sources:**

- The California Urban Streams Restoration Program (USRP) provides grants to local communities for projects to reduce flooding and erosion and associated property damages; restore, enhance, or protect the natural ecological values of streams; and promote community involvement, education, and stewardship. http://www.water.ca.gov/urbanstreams/

**Sector Overlap:** Biodiversity and Habitat

**Strategy 4.5: Implement general plan safety elements through zoning and subdivisions practices that restrict development in floodplains and landslide hazard areas.** Minimize or avoid development in 100-year (1 percent/year) floodplains and landslide areas. Use commonly applied hazard mitigation practices through zoning and subdivision reviews for new developments.

**Description:** This strategy includes a combination of a variety of commonly used zoning and subdivision practices, including (1) restricting allowable residential densities in hazardous areas, reducing the potential number of structures at risk; (2) clustering development or setting it back from flood hazard areas to reduce exposure; (3) transferring allowable density from hazardous sites to safer areas; (4) adopting slope-density formulas limiting the number of dwellings on hillsides subject to slippage or subsidence; (5) modifying proposed parcel boundaries and street locations to avoid hazardous areas; and (6) requiring multiple ingress and egress points for emergency access and evacuation.

**Factors to Consider**: Together with other examples below, these practices represent a powerful combination of tools to strengthen natural hazard mitigation in the course of day-to-day development planning. When applying them, however, communities should consider factors such as cost, environmental impacts, funding sources, timing, and private property rights.

**Examples of Applications:** Also commonly used is an array of complementary techniques for minimizing or avoiding development in flood- and landslide hazard-prone areas:

- Purchase of agricultural and conservation easements by private land trusts;
- Establishment of open space easements;
- Donation property for tax credits;
- Acquisition of land or development rights using developer fee or bond financing; and
- Limitations on infrastructure provision and extensions.

**Sources of Information:**

- Cal EMA. 2010 California Multi-Hazard Mitigation Plan. http://hazardmitigation.calema.ca.gov/docs/2010_SHMP_Final.pdf

**Strategy 4.6: Implement Senate Bill 5 (2007) in communities within the Sacramento-San Joaquin Drainage District.** Amend local general plans and zoning to include information on the Central Valley Flood Protection Plan (CVFPP) upon its adoption by the Central Valley Flood Protection Board.

**Description:** The Central Valley Flood Protection Act, enacted by SB 5, seeks to address flooding problems in portions of the Delta by directing the California Department of Water Resources (DWR) and the Central

Valley Flood Protection Board (CVFPB) to prepare and adopt a Central Valley Flood Protection Plan (CVFPP) by July 1, 2012. The purpose of the CVFPP is to establish a system-wide approach to improving flood management in the areas currently receiving some amount of flood protection from the existing facilities of the State Plan of Flood Control. Cities and counties within the boundaries of the Central Valley Flood Protection District must amend their general plans to conform to the CVFPP within 24 months following its adoption, and must amend their zoning to conform within 36 months. Once general plan and zoning ordinance amendments are enacted, the approval of development agreements and subdivision maps is subject to restrictions in flood hazard zones. Central Valley counties are obligated to develop flood emergency plans within 24 months of CVFPP adoption.

**Factors to Consider:** Hearings are underway during the spring of 2012 regarding the environmental impact report (EIR) for the CVFPP. Local jurisdictions are encouraged by DWR to participate in the hearings leading to adoption of the CVFPP by the CVFPB by July 1, 2012.

**Examples of Applications:**

- The CVFPP is part of a larger bond program approved by California voters in 2006 following Hurricane Katrina in New Orleans and the Gulf Coast states. The voter-approved $4.09 billion Proposition 1E (the Disaster Preparedness and Flood Prevention Bond Act of 2006) is funding flood management projects, including repairs and improvements to levees, weirs, bypasses, and other flood control facilities throughout the state. Proposition 1E allocates $3 billion to repair and improve state and federal facilities that are part of the State Plan of Flood Control for the Central Valley and to reduce the risks of levee failure in the Sacramento-San Joaquin Delta. The voter-approved $5.4-billion Proposition 84 (the Safe Water Quality, Supply, Flood Control, River and Coastal Protection Act of 2006) will allocate about $1.2 billion in additional funding beyond for flood control projects, including the Delta Levee Program, State Flood Control Subventions Program, and floodplain evaluation and delineations.

**Sources of Information:**

- Cal EMA. 2010 California Multi-Hazard Mitigation Plan. http://hazardmitigation.calema.ca.gov/docs/2010_SHMP_Final.pdf
- DWR. FloodSafe California. Powerpoint Presentation: "Central Valley Flood Protection, Implementing SB 5 (Machado, Florez, Wolk, Steinberg, and Laird)." http://www.water.ca.gov/floodsafe/docs/Central_Valley_Flood_Protection_Plan.pdf

### Strategy 4.7: Develop a water recycling program.

**Description:** Recycling water is a water management strategy that relies on reuse of already acquired local water. It may also be an energy-efficient option in some regions. Approved uses of recycled water are identified in Title 22 of the California Code of Regulations (http://www.cdph.ca.gov/certlic/drinkingwater/Documents/Recharge/Purplebookupdate6-01.PDF)

Recycling water means reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing, and replenishing a groundwater basin. A recycling program could therefore promote both municipal and onsite water reuse.

**Factors to Consider:** The level of wastewater treatment should match the water quality needed for the desired type of reuse. For example, water for landscape irrigation requires less treatment than recycled water for drinking water. Onsite water recycling, often called gray water recycling, includes wastewater from

bathroom sinks, bath and shower drains, and clothes washing drains that is reused within the same building or property. Therefore, wastewater and water agencies should collaboratively adopt policies and develop facility plans that promote the use of recycled water for all appropriate, cost-effective uses while protecting public health.

**Examples of Applications:**

- City of San Diego Water Purification Demonstration Project: http://www.sandiego.gov/water/water-reuse/demo/
- The City of San Luis Obispo has a recycled water program in which treated water is used for non-potable uses such as irrigation of City-owned park areas, agriculture, and construction areas. The procedures for recycled water can be reviewed here: www.slocity.org/utilities/download/reuseprocedures.pdf

**Sources of Information:**

- United States Environmental Protection Agency. 2012. Water Recycling and Reuse: The Environmental Benefits. Retrieved from: http://www.epa.gov/region9/water/recycling/
- California Air Pollution Control Officers Associations. 2010. Quantifying Greenhouse Gas Mitigation Measures. Retrieved from: http://www.capcoa.org/wp-content/uploads/2012/03/CAPCOA-ModelPolicies-6-12-09-915am.pdf (Reclaimed water is Strategy WSW-1 [p. 332].)

**Funding Sources:**

- California State Water Resources Control Board - Water Recycling Funding Program: http://www.waterboards.ca.gov/water_issues/programs/grants_loans/water_recycling/

**Strategy 4.8: Implement tiered pricing to reduce water consumption and demand.** Increase the incentive to consumers to be more thoughtful about water use by pricing water to reflect its value.

**Description:** In a tiered pricing format, the rate charged for water consumption each month depends on the level (tier) of consumption. Water is the least expensive when used within the first tier. When a customer's water use exceeds the tier's limit, the customer is charged at a higher, second-tier rate on the excess usage. This process repeats as consumption continues into higher tiers.

**Factors to Consider:** Tiered pricing can only implemented once metering has been established. Public education and outreach must accompany the implementation of a tiered pricing program, to clearly explain the process and emphasize the benefits of water conservation. Typically, the more dramatic the rise in cost from tier to tier, the greater the incentive to conserve water. Conversely, a less steep tiered pricing structure may not produce the desired level of conservation.

**Examples of Applications and Sources of Information:**

- Equinox Center. 2009. A Primer on Water Pricing in the San Diego Region. Retrieved from http://www.equinoxcenter.org/assets/files/pdf/Equinox%20Water_Pricing_Brief%20102609.pdf

**Strategy 4.9: Increase "above-the-dam" regional natural water storage systems.** Restore meadows and apply forest treatments to allow for increases in water storage and recharge of the groundwater supply.

**Description:** "Above-the-dam" storage refers to natural, ecosystem-based processes of storing water in mountainous areas, particularly in the Sierra. Meadow restoration is one example and has the co-benefits of improving ecological health and restoring and extending habitat. Meadow restoration has an additional

benefit as an adaptation strategy, in that it provides habitat corridors that facilitate species migration in response to a warming climate. Furthermore, improving forest health and resiliency through land management practices that reduce fire fuel loading will also contribute positively to the quality, quantity, and late season storage of water in the Sierra Nevada.

**Factors to Consider:** Cost-benefit analysis of increasing manmade reservoir capacity vs. implementing ecosystem restoration should incorporate the co-benefits of meadow restoration and forest treatment listed above. Furthermore, groundwater recharge through the ecosystem also reduces the impact of flooding, which is more likely to occur with the faster snowmelt predicted throughout the remainder of the century.

**Examples of Applications and Sources of Information:**

- California Natural Resources Agency Sierra Nevada Conservancy. 2009. The climate action plan of the Sierra Nevada: A regional approach to address climate change version 1.0. Auburn, CA: California Natural Resources Agency. http://www.sierranevada.ca.gov/docs/climate_action_plan-1.pdf

**Sector Overlap:** Biodiversity and Habitat, Forest and Rangeland

## 5.0 Forest and Rangeland

Climate change is projected to alter the frequency and severity of wildfire. Strategies in this sector focus either on reduction of the fire risk itself (thinning and prescribed burns) or reducing vulnerability to the risk (management of the wildland-urban interface).

**Strategy 5.1: Develop integrated plans for mitigating wildland fire impacts in wildland-urban interface (WUI) areas through (1) concurrent adoption and/or updating general plan safety elements and local hazard mitigation plans, and (2) implementation of the state's defensible space Fire Hazard Severity Zones laws.** Evaluate projected risks of wildfires and set priorities for actions to reduce potential losses through mitigation modifying existing and new development In WUI areas. Regulate development in and adjacent to areas with steep canyons, arroyos, and fire-prone vegetation. Require development in WUI areas susceptible to wildfires to provide a defensible zone to inhibit the spread of wildfires and to be responsible for fire prevention activities (e.g., visible house numbering and use of fire-resistant and fire-retardant building and landscape materials). Increase programmed, coordinated efforts to reduce the increased fire risks a result of climate change in WUI areas through vegetation management and code enforcement.

**Description:** Communities should update general plan safety elements, and, where applicable, local hazard mitigation plans to account for the projected impacts of climate change on wildland fire threats in WUI areas. Jurisdictions should evaluate building and land use planning practices in WUI areas and implement actions designed to reduce fuel, ignition sources, and fire spread risk created by new development through actions identified in safety elements and local hazard mitigation plans. Jurisdictions should implement Public Resources Code Section 4291, California's defensible space law, which deals with managing vegetation within 100 feet of structures. Jurisdictions should also implement Public Resources Code Sections 4201-4204 and Government Code Sections 51175-89, the state's Fire Hazard Severity Zones law, which describes fire hazards and risk and prescribes specific structural fire-retardant construction measures within Very High Fire Hazard Severity Zones within State Responsibility Areas (SRAs) and Local Responsibility Areas (LRAs).

**Factors to Consider:** California law requires each city and county to prepare a general plan, including a safety element that identifies local hazards such as wildfires. Federal disaster law requires preparation of local hazard mitigation plans as a precondition for federal mitigation grant fund eligibility. As new knowledge on wildfire threats and risk becomes available, such information should be added to general plan safety elements and local hazard mitigation plans through concurrent adoption/updates. Such updates should be integrated with local actions taken to implement Public Resources Code Section 4291, the defensible space law, and Public Resources Code Sections 4201-4204 and Government Code Sections 51175-89, the Fire Hazard Severity Zones law.

**Examples of Applications and Sources of Information:**

- Cal EMA. 2010 California Multi-Hazard Mitigation Plan. http://hazardmitigation.calema.ca.gov/docs/2010_SHMP_Final.pdf
- Governor's Office of Planning and Research. 2003. General Plan Guidelines. http://cnps.org/cnps/conservation/conference/2006/General_Plan_Guidelines_Overview%202003.pdf
- Cal EMA. Hazard Mitigation Web Portal: http://hazardmitigation.calema.ca.gov/
- Cal FIRE resources.
    - http://frap.fire.ca.gov/projects/hazard/fhz.html
    - http://frap.fire.ca.gov/projects/hazard/PRC_4201-4204.pdf
    - http://frap.fire.ca.gov/projects/hazard/GC_51175-51189.pdf

### Strategy 5.2: Establish a monitoring program to track forest health.

**Description:** Some of the most difficult impacts of climate change to address are those that progress slowly and are therefore more difficult to recognize. Shifts in forest health and invasive species spread can have detrimental impacts on biodiversity and wildfire frequency. Without careful monitoring, these changes may be missed during the early stages. A monitoring program allows for management of these systems to be responsive and tailored to regional needs. A forest monitoring program enables identification of areas where insects and disease, invasive species, and tree mortality levels are high or increasing. These factors not only relate to forest health, but also wildfire risk.

**Factors to Consider:** A monitoring program must be tailored to the setting being evaluated. The potential threats to a forest ecosystem should be defined as specifically as possible to allow for higher resolution in obtained data. In addition, a system for reviewing monitoring data and integrating that data into management policy must also be established.

**Examples of Applications and Sources of Information:**

- California Department of Forestry and Fire Protection. 2012. Adaptation to Climate Change. Retrieved from http://www.fire.ca.gov/resource_mgt/resource_mgt_eprp_climate/climate_change_adaptation.php
- California Department of Fish and Game. 2007. California Wildlife: Conservation Challenges - California's Wildlife Action Plan. Sacramento: author. Retrieved from: www.dfg.ca.gov/habitats/wdp/

**Sector Overlap:** Biodiversity and Habitat

**Strategy 5.3:** Reintroduce fire (controlled or prescribed burns) to fire-prone ecosystems.
Description: In areas of the state, there is a legacy of over a century of fire suppression that has resulted in high fuel loads. Increased temperature and reduced precipitation increase the risk associated with these

fuel loads. Managed fire allows for past ecosystem function to be restored and reduces the risk of wildfire associated with the history of fire suppression. Controlled burns allow maintenance of function and structure amidst increasing threat of destruction from evolving fire frequency and severity.

**Factors to Consider:** There is risk associated with prescribed burns. The increased fuel load that a prescribed burn seeks to reduce also can mean that the fire can get out of control. The conditions, timing, safety planning, and noticing to surrounding community members must be carefully planned. The other risk that must be managed and addressed is smoke management, because smoke can travel great distances and pose a health risk to vulnerable populations.

**Examples of Applications:**

- The Long Canyon-Pismo Vegetation Management Plan Prescribed Burn can be reviewed here: http://www.pismobeach.org/index.aspx?NID=575

**Sources of Information:**

- Cayan, D., A. Lynd, M. Hanemann, G. Franco, and B. Croes. 2006. Scenarios of climate change in California: An overview. Sacramento, CA: California Climate Change Center. Retrieved from http://www.climatechange.ca.gov/
- California Air Resources Board. 2003. Prescribed Burning and Smoke Management. Retrieved from http://www.arb.ca.gov/smp/progdev/pubeduc/pbfs.pdf

**Sector Overlap:** Biodiversity and Habitat

### Strategy 5.3: Reduce accumulated fuel load through thinning and brush removal.

**Description:** Past fire suppression practices have resulted in increased fuel load. Thinning and brush removal are approaches to reduce this load and associated fire risk. Communities should collaborate with regional conservation districts, Cal FIRE, and other local entities to identify high fire risk and high value areas. Based on this assessment, this group should work together to devise a management plan. Thinning is one of several management practices that can reduce fuel load.

**Factors to Consider:** Thinning is an effective means to mitigate particular types of fire risk such as crown burning. It is also more appropriate in certain forest types than others. Thinning can vary in scale and intensity (e.g., mechanical thinning, hand thinning, and brush removal). The most appropriate areas in which to engage in thinning and the approach must be carefully considered.

**Examples of Applications:**

- San Diego County. 2010. San Diego County Multi-Jurisdiction Hazard Mitigation Plan San Diego County, California. Retrieved from http://www.co.san-diego.ca.us/oes/docs/2010_HazMit_Plan.pdf
- Humboldt County. 2007. General Plan – Safety Element. Retrieved from http://co.humboldt.ca.us/gpu/docs/prelimhearingdraft/group3/safetyelement3-21-07posted.pdf

**Sources of Information:**

- Keithley, C. and C. Bleier. 2008. An Adaptation Plan for California's Forest Sector and Rangelands. California Department of Forestry and Fire Protection. Retrieved from http://www.fire.ca.gov/resource_mgt/resource_mgt_EPRP_Climate/Climate_change_Forestry_Adaptation_strategies_12-11-10.pdf
- California Department of Forestry and Fire Protection. 2012. Adaptation to Climate Change. Retrieved from http://www.fire.ca.gov/resource_mgt/resource_mgt_eprp_climate/climate_change_adaptation.php

## 6.0 Biodiversity and Habitat

For local jurisdictions, the preservation of biodiversity and habitat threatened by climate change often requires collaboration, or at least awareness, of efforts occurring at larger scales. Provision of adequate habitat to allow any necessary wildlife migration may not be possible in small jurisdictions, but these communities can position their efforts to complement larger efforts by carefully managing open space and creating connections between areas of undeveloped land.

**Strategy 6.1: Identify and protect locations where native species may shift or lose habitat due to climate change impacts (sea level rise, loss of wetlands, warmer temperatures, drought).** Modify conservation and open space management priorities to include species adaption to the effects of climate change. Description: The modification of management practice can include actions such as purchasing and protecting of habitat corridors that move up in elevation, so that species have somewhere to migrate as the temperatures increase. Communities have several plans and policies that govern the acquisition, establishment, and management of parks and open space. These should be updated to assure that adaptation needs are included in the criteria used for determining actions.

**Factors to Consider:** Communities should identify the vulnerable species and habitats in their region as well as the threats that climate change poses. The type of land management or park establishment needed should result from this evaluation.

**Examples of Applications:**

- San Luis Obispo County. 2011. EnergyWise Plan. Retrieved from http://www.slocounty.ca.gov/Assets/PL/CAP-LUCE/final/SLOCoCAP_Board_Approved-Complete+Doc.pdf

**Sources of Information:**

- California Department of Parks and Recreation. 2007. California State Parks' response to climate change (p.1). Retrieved from http://ohv.parks.ca.gov/pages/1140/files/09-11-07revisedohmvr%20commission%20climate%20change%20synopsis.pdf

**Strategy 6.2: Collaborate with agencies managing public lands to identify, develop, or maintain corridors and linkages between undeveloped areas.**

**Description:** Species that have several populations distributed over a larger range are less susceptible to climate impacts. Connected blocks of habitat are less likely to produce fragmented, small species populations. As communities acquire additional open space lands, those that adjoin existing public land should be given priority. In addition, climate change should be considered in the restoration and/or management of these properties. Communities located near state or federal public lands can coordinate their land conservation practices and open space management to foster landscape connectivity.

**Factors to Consider:** The species and habitats most vulnerable to climate change in a region must be evaluated to identify adaptation needs. This can provide information regarding minimum corridor width and habitat needs.

**Examples of Applications and Sources of Information:**

- San Diego County. 2011. San Diego County General Plan – Conservation and Open Space Element. Retrieved from http://www.sdcounty.ca.gov/dplu/generalplan.html

**Strategy 6.3: Use purchase of development (PDR) or conservation easements to protect climate-vulnerable habitats. Protect these lands to allow for migration and to link fragmented landscapes.**

**Description:** PDR or conservation easements allow for compensation of land owners. There are often limited funds for completion of a PDR or easement. For that reason, careful consideration of the habitat and species associated with a property is required. The focus should be on allowing space for migration or linking larger tracts of protected land to create a corridor.

**Factors to Consider:** These projects are often best pursued in collaboration with a local land conservancy or land trust. These organizations are familiar with deed limitations and often have relationships with land owners in their region. PDRs are voluntary and therefore rely on a good relationship with a community. Restoration may be required on these sites and long-term monitoring should be initiated to evaluate ecological function.

**Examples of Applications:**

- Feifel, K. 2010. Adding the Impacts of Climate Change to a Strategic Plan: Big Sur Land Trust [Case study on a project of the Big Sur Land Trust]. Product of EcoAdapt's State of Adaptation Program. Retrieved from CAKE: http://www.cakex.org/case-studies/2830

**Sources of Information:**

- Byers, E and K. Marchetti. 2005. The Conservation Easement Handbook. Trust for Public Land and Land Trust Alliance. Retrieved from http://learningcenter.lta.org/attached-files/0/57/5752/CEH_preview.pdf
- Western Governors' Association, Trust for Public Land, and National Cattlemen's Beef Association. 2001. Purchase of Development Rights. Retrieved from http://www.westgov.org/wga/publicat/pdr.pdf

## 7.0 Agriculture

For local jurisdictions, agriculture is a difficult sector to address directly. Agricultural activities primarily take place on private land and obtain their own water supply. Local and regional jurisdictions can take action to support climate-friendly and adaptive changes by farmers. Incentives and resources can also be provided to ease the strain placed on agriculture by climate change.

**Strategy 7.1: Promote economic diversity. Adjust land use regulations (e.g.,agricultural zoning) to encourage the diversification of potential sources of farm income, including value-added products, agricultural tourism, roadside stands, organic farming, and farmers markets.**

**Description:** Diverse income sources can serve to reduce the financial consequences of climate impacts on agricultural land owners. Adjustment of land use regulations will allow, and encourage, practices such as agricultural tourism or other commercial operations.
Factors to Consider: Adjustments to allow agricultural tourism must carefully consider the adjacent land owner and the potential consequences of new commercial operations such as increased traffic.

**Examples of Applications:** Several counties in California have established agricultural tourism in their zoning codes:

- County of San Diego. 2010. County of San Diego Zoning Code. San Diego, CA. Retrieved from http://www.sdcounty.ca.gov/dplu/zoning/index.html
- County of El Dorado. 2010. El Dorado County Code Title 17: El Dorado County Zoning Ordinance. Retrieved from http://www.edcgov.us/Government/Planning/Zoning_Ordinance_and_Maps.aspx
- County of Lake. 2005. Lake County Zoning Code. Retrieved from http://www.co.lake.ca.us/Government/Directory/Community_Development/ZoneOrd.htm

**Sources of Information:**

- Barbieri, C., E. Mahoney, and L. Butler. 2008. Understanding the Nature and Extent of Farm and Ranch Diversification in North America. Rural Sociology, 73(2), 205-229.

**Strategy 7.2: Assist and educate farmers in adapting to climate change.** Work with entities such as resource conservation districts, cooperative extensions, and other agricultural organizations to introduce adaptation techniques and shorten the time it takes for new scientific findings and adaptive approaches to reach farmers.

**Description:** Agricultural associations, cooperative extensions, resource conservation districts, and other entities are positioned to understand the needs and concerns of farmers. Working with these entities will allow jurisdictions to identify those agricultural techniques and information most likely to be beneficial to local farmers. Methods can include distribution of educational materials, workshops, or demonstration/training sessions on adaptive techniques.

**Factors to Consider:** Communities should identify organizations most closely aligned with local farmers to assure information reaches its intended audience. Strategies and support should be specifically tailored to local needs.

**Examples of Applications and Sources of Information:**

- San Luis Obispo County. 2011. EnergyWise Plan. Retrieved from http://www.slocounty.ca.gov/Assets/PL/CAP-LUCE/final/SLOCoCAP_Board_Approved-Complete+Doc.pdf

**Strategy 7.3: Support alternative irrigation techniques (e.g., subsurface drip irrigation) to reduce water use and encourage use of climate-sensitive water supplies**

**Description:** Local jurisdictions can promote alternative irrigation techniques through partial or full coverage of cost and technical support. Water use savings result in reduced greenhouse gases. In some cases, the conversion to alternative irrigation techniques can be funded as offsite mitigation of greenhouse emissions as part of a project's CEQA review. An incentive program should be accompanied by an outreach program to raise awareness of the program and irrigation alternatives.

**Factors to Consider:** The current irrigation techniques in a region and the growing requirements for crops must be evaluated in developing a program and/or fund to support irrigation upgrades. Changed irrigation practices may not be useful for all crops and entail substantial investment, labor, and energy. A program focused on irrigation techniques should be developed in collaboration with local agricultural organizations or resource conservation districts.

**Examples of Applications and Sources of Information:**

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# Appendix A

## Cal-Adapt Climate Model Summary

Cal-Adapt utilizes four climate models, described below, as the bases of its climate projections. They each measure climate sensitivity, or how the environment reacts to given levels of GHG emissions. Additionally, each model is an example of a general circulation (GCM) model. A GCM is a complex, three-dimensional system representing the effects of such factors as reflective and absorptive properties of atmospheric water vapor, greenhouse gas concentrations, clouds, annual and daily solar heating, ocean temperatures, and ice boundaries (CEC, 2011).

Each model has its advantages and disadvantages, and none should be seen as the most accurate projection of future climate. The International Panel on Climate Change has used the models in its assessment reports, but these are four among many. As such, they represent only a portion of the range of climate projections, which are displayed in Figure A-1 below. Additionally, the resolution (level of detail) is limited in all the models to a broad scale that may not account for differences in topography in any given area. Therefore, communities with sufficient resources may wish to consider commissioning more-detailed, localized modeling.
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**PCM1: National Center for Atmospheric Research (NCAR) Parallel Climate Model 1**
This is a coupled climate model, meaning it combines models for atmosphere (Community Climate Model), ocean (Parallel Ocean Program), sea ice (Community Sea Ice Model), and land (Land Surface Model). It is a predecessor to CCSM3 (described in the next section). It has a T42 spatial resolution, which translates to 2.8 degrees at the equator.

*Advantages:* Based on a study comparing actual temperature and precipitation in the 20th century to what the model would have predicted, PCM1 had among the lowest statistical biases (Salathe and Peacock, n.d.).

*Disadvantages:* PCM1 is an older model using a less-refined resolution (T42) than is available in more current models. A lower resolution means the model is not as capable of accounting for topographical differences (such as mountains) and how those affect temperature and precipitation.

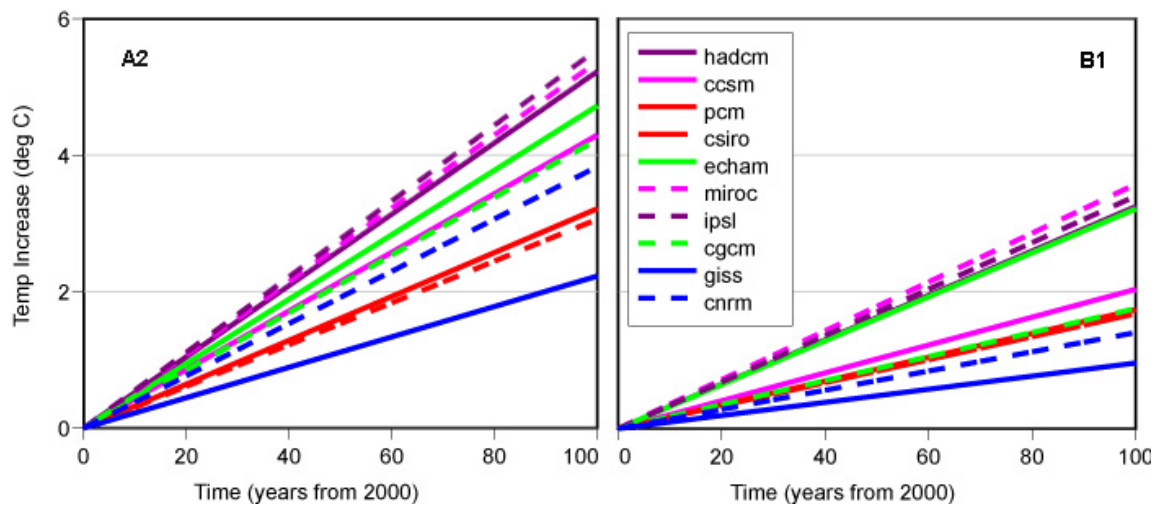
**CCSM3 - Community Climate System Model, version 3**
Like PCM1, this is a coupled model. It is a linked system of four climate models—an atmosphere model (Community Atmosphere Model, a land-surface model (Community Land Model), an ocean model (Parallel Ocean Program), and a sea-ice model (Community Sea Ice Model)—connected by software that allows each component model to feed into the other. CCSM3 is currently not available as a selection for Cal-Adapt's Wildfire: Fire Risk Map tool (http://cal-adapt.org/fire/).

*Advantages:* CCSM3 is a high-resolution model (T85). It is near the middle of 10 different modeled trends for both A2 and B1 scenarios as shown in Figure A-1. Like PCM1, it is among the better models when measured against 20th century temperature and precipitation in winter and summer months (Salathe, Eric and Cynthia Peacock, n.d. "IPCC AR4 Climate Model Comparisons").

*Disadvantages:* CCSM3 produces sea surface temperatures in the western coastal regions that are warmer than observed. It also has a slight low bias on albedo measurements when ice is covered by dry snow (Collins et al., 2006).

Figure A-1: Climate Models Annual Temperature Trends

**Figure A-1: Climate Models Annual Temperature Trends**




Note: climate models used by Cal-Adapt depicted here are CCSM, PCM, and CNRM.
GFDL was not included in the comparison.
[*Source: Salathe and Peacock. n.d.* IPCC AR4 climate model comparisons. *Retrieved from* *http://www.atmos.washington.edu/~salathe/AR4_Climate_Models/Trends/summary_trend.html* ]

Note: climate models used by Cal-Adapt depicted here are CCSM, PCM, and CNRM.
GFDL was not included in the comparison.
[Source: Salathe and Peacock. n.d. IPCC AR4 climate model comparisons. Retrieved from http://www.atmos.washington.edu/~salathe/AR4_Climate_Models/Trends/summary_trend.html ]

**GFDL – NOAA Geophysical Fluid Dynamics Laboratory Coupled Climate Model 2.1**
GFDL is a model created by the National Oceanographic and Atmospheric Administration. It is another coupled climate model, combining atmosphere (AM2P13), ocean (OMP34), land (LM2), and sea ice (SIS) models. Cal-Adapt currently uses the GFDL model alone for its Temperature: Extreme Heat Tool (http://cal-adapt.org/temperature/heat/).

*Advantages:* GFDL simulates a realistic climate compared to other models (Reichler and Kim, 2008) and was shown to be among the most reliable models at forecasting El Niño cycles (van Oldenborgh, G.J., S. Y. Philip, and M Collins, 2005).

*Disadvantages:* Like other lower-resolution models, it is not as capable of accounting for topographical differences (such as mountains) and how those affect temperature and precipitation on a narrower geographic scale.

**CNRM - Centre National de Recherches Météorologiques Coupled Global Climate Model, version 3**
This is a combined climate model like CCSM3, but uses five models instead of four: atmosphere (ARPEGE); ocean (NEMO); sea-ice (GELATO); land (SURFEX); and river routing and river water discharge to the oceans (TRIP). (Source: CNRM; http://www.cnrm-game.fr/spip.php?article126&lang=en)

*Advantages:* Of the models tested in a University of Washington study (Salathe and Peacock, n.d.) it had the best agreement between modeled 20th century annual temperature and precipitation cycles with actual temperatures and precipitation. Among the modeled temperature trends (Figure A-1), it is in the middle for the A2 scenario.

*Disadvantages:* The model has a lower spatial resolution than other models, which may distort its projections. It also has larger biases on temperature and precipitation in the months of December, January, and February (Salathe and Peacock, n.d.)

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**Additional Resources**

*Climate Modeling in General*

- NOAA – Modeling Climate: http://www.research.noaa.gov/climate/t_modeling.html

*All Models*

- CMIP3 Climate Model Documentation, References, and Links: http://www-pcmdi.llnl.gov/ipcc/model_documentation/ipcc_model_documentation.php
- IPCC AR4 Climate Model Comparisons: http://www.atmos.washington.edu/~salathe/AR4_Climate_Models/ (excludes GFDL)

*CCSM3*

- Collins et al. (2005). The Community Climate System Model Version 3 (CCSM3), www.deas.harvard.edu/climate/seminars/pdfs/CCSM2006.pdf
- Model Information of Potential Use to the IPCC Lead Authors and the AR4 – CCSM3, http://www-pcmdi.llnl.gov/ipcc/model_documentation/CCSM3.htm

*CNRM*

- Model Information of Potential Use to the IPCC Lead Authors and the AR4 - CNRM-CM3 (version used for IPCC AR4), http://www-pcmdi.llnl.gov/ipcc/model_documentation/CNRM-CM3.htm

*GFDL*

- Model Information of Potential Use to the IPCC Lead Authors and the AR4 - GFDL-CM2.0 and GFDL-CM2.1, http://www-pcmdi.llnl.gov/ipcc/model_documentation/GFDL-cm2.htm

*PCM1*

- http://www.cgd.ucar.edu/pcm/
- http://www-pcmdi.llnl.gov/ipcc/model_documentation/PCM.htm