ClimateWise®

Integrated Climate Change Adaptation Planning in San Luis Obispo County

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EXECUTIVE SUMMARY

Climate change is a global phenomenon that has the potential for severe local impacts to agriculture, human health, natural resources, infrastructure, emergency response needs, tourism, and many other facets of society. Climate change impacts are expected to exacerbate the vulnerability of certain populations and sectors of society. By identifying and addressing underlying vulnerabilities early, decision makers in San Luis Obispo can increase the resilience of both the community and the resources it depends on to climate change.

This report provides a suite of adaptation strategies that was developed by local leaders and experts during a series of workshops in 2009-2010. We view these strategies as a critical first step in what will need to be an ongoing process as the climate, other stressors, and the scientific understanding of the earth's processes continue to change over time. By integrating adaptation strategies across the different sectors of society, county leaders will reduce conflict among diverse interests for limited resources, such as water, while increasing communication and lowering overall costs.

Based on climate change model projections from three global climate models (provided by NCCSP), as well as peer-reviewed scientific publications, local experts and leaders identified the following as changes that could occur in San Luis Obispo County by the end of this century:

- Hotter, drier, and longer summers
- More severe storms
- Accelerating sea level rise
- Increase in wildfire
- Loss of many oak and pine forests
- Eroding coastal bluffs; declining wetlands, marshes, and estuaries
- Declines in water quality and flow in streams and rivers
- Increase in erosion and sediment
- Lower groundwater recharge rates
- Loss of some native species and functioning ecosystems
- Less productive range for cattle
- Increase in invasive species
- Increase in severe heat days that cause illness and death
- Increase in mental illness
- Increase in natural disasters (floods, droughts, fires)
- Stress to water and flood infrastructure
- Changes to agriculture

Workshop participants considered both climate change impacts and on-the-ground vulnerabilities as they developed a suite of recommendations for reducing the impacts of climate change, including:

General

- Drastic reduction in greenhouse gas emissions to limit the magnitude of climate change

Socioeconomic Systems

Health and Emergency Preparedness

- Expand outreach and education on emergency preparedness
- Identify and target vulnerable populations for outreach

- Bolster wildfire management planning in the region
- Increase local food production and independence
- Reduce vehicle miles associated with food delivery
- Promote healthy lifestyle practices

Agriculture and Related Tourism

- Make water conservation a top priority
- Reduce greenhouse gas emissions from agricultural activities and increase carbon sequestration in agricultural soils
- Conserve agricultural land through the development of new tools and economic incentives
- Provide additional support for farm workers and employees of the agricultural tourism industry

Water Resources and Infrastructure

- Work with water agencies, mutual water companies and regional planning agencies to monitor and reduce agricultural water use
- Collaborate across jurisdictions for cooperative basin planning
- Enforce the Clean Water Act
- Encourage low impact development, natural filtration, and urban runoff catchments

Infrastructure

- Work with the private sector to achieve smart growth policies and avoid building in areas at risk of floods and fire
- Encourage alternative transportation
- Encourage energy conservation and alternative energy development in areas with low ecological impacts
- Increase the amount of renewable energy available to residents

Coastal and Marine Resources and Tourism

- Identify high-risk areas and map failing infrastructure to prioritize repairs and improvements
- Reassess coastal land use policies with climate change in mind
- Protect species migration corridors, new habitats and adjacent habitat (buffers)
- Consider ecotourism and other strategies to draw visitors and boost local business while minimizing the impacts to natural resources

Species and Ecosystems

Coastal and Nearshore Marine

- Protect areas neighboring dunes, coastal marshes and wetlands to allow shifts as the sea level rises
- Protect habitat for sensitive species more aggressively and effectively to maintain resilient populations
- Institute a county- or state-wide policy on coastal structures, allowing for dynamic coastlines

Freshwater Aquatic and Riparian

- Reduce groundwater use by communities and agriculture
- Research groundwater availability and develop a sustainable master groundwater plan
- Improve upland land management practices to reduce sediment inputs to streams and rivers

Woodlands and Forests

- Target oak woodlands on private ranches for improved management
- Reform grazing practices to improve oak recruitment, riparian vegetation, and water quality

- Identify and conserve areas especially important for wildlife under climate change
- Develop drought resistant varieties of oak
- Conduct research to identify effective management options

Grasslands and Shrublands

- Reduce fire risk in salt bush
- Map and conserve corridors that allow species to move to new areas as the climate changes
- Increase monitoring of populations of many species
- Identify new opportunities for restoration of native habitats
- Limit new development, especially of renewable energy, to previously disturbed sites

WORKSHOP PARTICIPANTS

The authors of this report acted primarily as facilitators during this process. The real work was done by the following people, who participated in workshops, contributed ideas, and devoted time and enthusiasm to make the process successful. The body of this report is a reflection of their expertise. We apologize for any oversight on our part if you participated in the process and your name is missing or misspelled.

Sue Aiken, Shani Alford, Larry Allen, Ray Allen, LynnDee Althouse, Doug Anderson, Jim App, Aeron Arlin Genet, Lisa Ashley, Cathlin Atchison, Melinda Avila, Della Barrett, Judith Bernstein, Ellen Béraud, Dan Berman, William Bianchi, Lisa Bodrogi, Penny Borenstein, Michael Boswell, Joe Brenner, Amy Breschini, Karen Bright, William H. Brooks, Lexie Brown, Jerry Bunin, Ellen Carroll, Andrew Carter, Tommy Carter, David Chipping, Dave Christensen, Andrew Christie, David Church, Claire Clark, Ross Clark, Fred Collins, Kevin Cooper, Joe Costello, Nora De Cuir, Susan DeCarli, Dusteve Devencenvi, Christine Dietrick, Phil Dunsmore, Ron De Carli, Steve Ela, Liana Forest, Ashley Frusch, Ted Ehring, Sonja Eriksson, Lewis Euler, Marilyn Farmer, Rex Farris, Chuck Fellows, Joy Fitzhugh, Al Fonzi, Warren Frace, Joy Fritz, Dave Garth, Bruce Gibson, Nick Gilman, Dan Gilmore, Jim Grant, Adrienne Greve, Kami Griffin, Melissa Guise, Rhian Gulassa, Jim Guthrie, Greg Haas, Dave Hacker, Jon Hall, John Hamon, Carrie Head, Kelly Heffernon, Bill Henry, AICP, Gordon Hensley, Adam Hill, Bob Hill, Jaime Hill, Deb Hillyard, Jess Huselid, Stacie Jacob, Lionel Johnston, Andrea Jones, Eugene Jud, Cynde Kasperovich, Trevor Keith, Eric Kelley, Randy Knight, Corey Kreioler, Aaron Lazanoff, Kristy Lazanoff, Chris Leppla, Katy Lewis, Katie Lichtig, John Lindsey, Stephanie Little, Melissa Locke, Aileen Loe, Elizabeth Lowham, Sue Luft, Maggie Macro, Patrick Mahan, George Maithonis, Don Maruska, Jan Marx, Steven Marx, Carrie Mattingly, Susan McDonald, June McIvor, Wade McKinney, Urban McLellan, David Morrow, Mike Multari, Kim Murry, Allyson Nakasone, Kevin O'Connor, Paavo Ogren, Brian Parker, James Patterson, Janice Peters, Gary Pierce, Gilbert Pitt, Mike Prater, Ron Rasmussen, Barbara B. Renshaw, Amanda Rice, Gerald Rioux, Christine Rogers, Dave Romero, Larry Saslaw, Tammy Seale, Allen Settle, Mark Skinner, Holly Sletteland, Patrick Smith, Kenneth Smokoska, David Sneed, Bob Stafford, Chuck Stevenson, AICP, Bill Tietje, Patti Toews, Barrie Valencia, Eric Veium, Joanna Verhoar, Stephnie Wald, Tim Walters, Tracy Wang, Chuck Ward, Nancy Watts, Dean Wendt, Jen Werner, Philip Westergaard, Ray Weymann, Mary White, Charles Whitney, Patricia Wilmore, Betty Winholtz, Michael Winn, Rosalie Wolff, Claudia Worthen, Lyle Yager

PURPOSE AND OVERVIEW

The purpose of this effort is to develop new strategies that will increase the resilience of both human and natural communities to near-term and long-term changes associated with a changing climate in San Luis Obispo County. As climate change progresses, increased stress to people and to the natural resources they rely on are expected. Actions taken now can reduce this stress and maintain the quality of life that residents of this exceptional and diverse region have come to enjoy. By preparing for climate change impacts in a cohesive and ecologically sound manner, San Luis Obispo County will not only reduce the vulnerability of community members to stressors such as drought and floods, but also maintain the value of services, such as tourism, flood abatement, water filtration, cattle forage, and pollination, that are provided by natural systems across the county.

This report reflects the collective efforts and insights of many people in San Luis Obispo County, including elected leaders, county planners, land managers, public health officials, concerned citizens, and others who joined us in four workshops that form the basis for this report. These individuals came together to discuss the threat of climate change to their community and to develop some initial strategies to reduce the community's vulnerability to this threat. The GEOS Institute and the Local Government Commission facilitated the exchange of information, but this report remains a reflection of input and opinion from local experts, leaders, and citizens.

Climate change "adaptation" refers to actions that communities, governments, and individuals take to reduce their vulnerability to climate change impacts. Climate change is well underway, and many changes are already apparent. Average global air temperature has already increased 1.4° F while the average sea level has risen eight inches over the last century (Cayan et al. 2009). Severe storm and wildfire frequency have increased throughout the western U.S. (Westerling et al. 2006). Globally, species of animals and plants are already on the move as a result of the warming climate (Root et

Kresge Foundation Funding

This effort was made possible by a grant from the Kresge Foundation. It is one of only a few pilot studies around the nation that provide integrated climate change adaptation planning across both natural and human communities. The strategies that were developed are intended to protect and enhance basic quality-of-life for residents, to be ecologically sound, and to work across sectors to provide co-benefits while reducing competition for scarce resources such as water and land.

San Luis Obispo County was chosen as a pilot location based on a number of factors, including high biological diversity, agricultural and wine industry importance, federal land ownership, coastal resources, Climate Action Plan progress, support from County officials, and others.

al. 2006). Changes are happening quickly and are expected to accelerate in the next few decades due to emissions that have already been released. While reducing greenhouse gases (referred to as climate change "mitigation") is absolutely vital for preventing more extreme climate change, many future impacts are unavoidable. Adaptation strategies recommended in this report are expected to reduce San Luis Obispo's vulnerability to the impacts of a changing climate, but by themselves these adaptive strategies will be insufficient over long time scales (50+ years) to keep the county's natural and social communities safe, if drastic and immediate cuts to emissions are not also made on a global scale.

Workshop participants discuss climate change adaptation strategies.

GLOBAL CHANGE

The IPCC (2007) and the U.S. Global Change Research Program (2009) agree that the evidence is "unequivocal" that the Earth's atmosphere and oceans are warming. They also agree that this warming is due primarily to human activities including deforestation and the emission of CO_2, methane, and other greenhouse gases. Global average temperature has increased 1.4° F over the last century and is expected to increase an additional 3.5 – 11.5° F by 2100 (Figure 1).

Increases in air and water temperature are expected to lead to substantial changes in many of the earth's systems. For example, storm severity is expected to increase, causing more destructive hurricanes (Bender et al. 2010) and sudden downpours that lead to flooding. Sea-level rise is expected to further accelerate throughout this century, from both warming of the ocean (warmer water takes up more space than colder water) and melting of ice caps and glaciers (USGCRP 2009).

A changing climate could further increase the vulnerability of those people who are already vulnerable, and those ecosystems that are already stressed. While wealthy nations and middle and upper class people will also experience the impacts of a changing climate, they are unlikely to suffer to the same extent that less-developed nations and people with fewer resources (even in wealthier nations like the U.S.) will experience. Similarly, intact ecosystems with high biodiversity will likely be more resilient than those that are already stressed and in decline. By reducing

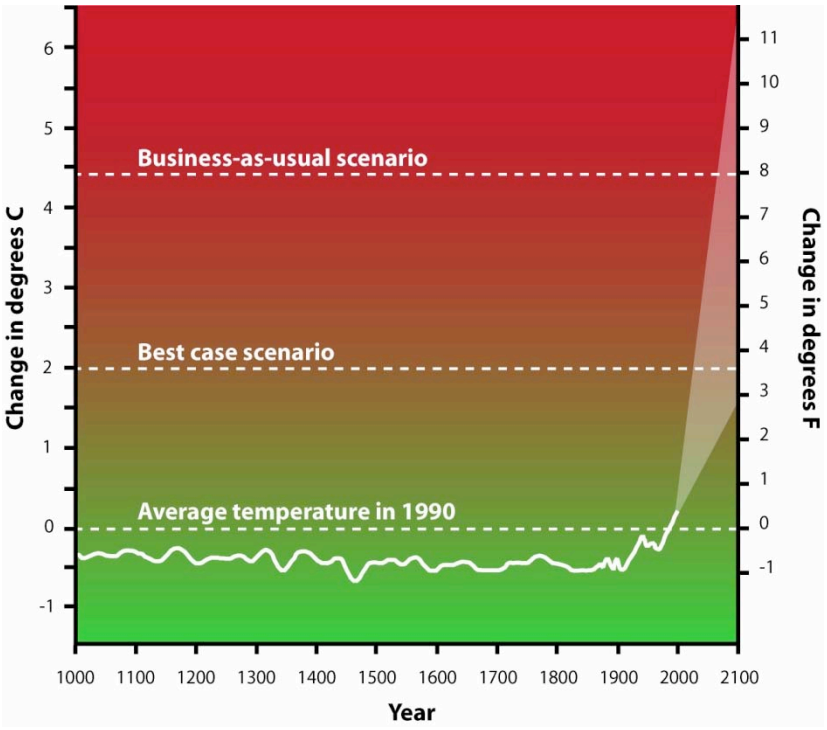


Figure 1. The last 1000 years in global mean temperature, in comparison to projected temperature for 2100. Drastic cuts in greenhouse gas emissions may lead to an increase of about 3° F by 2100 while the current emissions trajectory could lead to an increase closer to 8° F and as high as 11° F (adapted from IPCC 2007).

the vulnerabilities of local communities and the natural resources they rely on, we can prepare now in a way that prevents some of the more severe impacts of a changing climate. This report provides a suite of initial strategies that can be implemented to reduce vulnerabilities. We view them as a critical first step in what will need to be an ongoing process as our climate, other concurrent factors and stressors, and our scientific understanding of these processes continue to change over time.

Approximately 30% of all species are at risk of extinction from climate change (Thomas et al. 2004). Because the climate is changing so quickly and dramatically compared to previous post-glacial periods, many species will be unable to adapt to the changes or move to new areas quickly enough to survive. Other species will lose important food resources or their breeding or migration timing will be disrupted by climate change. As ecosystems unravel, many ecosystem services, such as flood control, water filtration, pollination, and timber production, could be compromised or lost.

Why make changes if the future is uncertain?

Climate model projections are uncertain. Different models project different future conditions, and future emissions are unknown. Why would we invest time and resources into planning for uncertainty?

There are 3 main reasons:

#1 – Planning for continued historic conditions sets us up for failure. All of our current planning mechanisms use history to plan for the future – such as drought frequency and severity, dam stability, flood risk to communities, etc. According to thousands of leading and independent scientists, the future is unlikely to resemble the past. The range of likely future conditions indicated by the climate models is far more likely than continued historical conditions.

#2 – We plan for uncertain conditions on a regular basis, and don't even realize it. Climate change is no different. Some examples include harvesting timber based on models of tree growth, planning new freeways based on 20-40 year projections of population growth and commute patterns, and buying fire insurance when we don't expect to have a fire. Even if climate change was unlikely (and its not), the costs (by some estimates, around 13% of national GDP by 2040) are so high that we would be prudent to plan proactively.

#3 – Taking action makes the community more resilient and vibrant, regardless of the actual trajectory of climate change. San Luis Obispo County is already at risk from extended drought, seawater intrusion into coastal wells, over pumping of groundwater, and loss of agricultural and natural lands to development. By addressing these and other issues now, the community's strength and resilience is expected to increase. Those strategies that benefit the county regardless of uncertain projections should be given priority.

The Value of Global Climate Models in Making Local Decisions

Climate change presents us with a serious challenge as we plan for the future. Our current planning strategies at all scales (local, regional, and national) rely on historical data to anticipate future conditions. Due to climate change and its associated impacts, however, the future is no longer expected to resemble the past. To determine what conditions we might expect in the future, climatologists create models based on physical, chemical, and biological processes that form the earth's climate system. These models vary in their level of detail and assumptions, making output and future scenarios variable. Taken as a group, however, climate models present a range of possible future conditions.

Emissions Scenario

Climate projections discussed in this report are based on the "business-as-usual" (A2) greenhouse gas emission scenario (IPCC 2007). This scenario closely followed the global emissions path of the late 1990s; a sharp rise in emissions since 2000 means that emissions of the past decade exceeded those used in the modeling in this report (Raupach et al. 2007; see also http://www.realclimate.org/index.php/archives/2010/06/recent-trends-in-co2-emissions/). Consequently, the climate projections reflected in this report may underestimate actual climate change. A concerted effort to lower emissions could, in contrast, lead to lower temperatures than those depicted in this report. Due to inertia in the climate system, mid-century projections are likely to occur, even if emissions are drastically reduced in the near future. Late-century projections, on the other hand, are highly uncertain.

Climate Models

Please see the companion report, "Projected Future Climatic and Ecological Conditions in San Luis Obispo County", for more information on the models, modeling assumptions, uncertainty, and projections (www.geosinstitute.org/images/stories/pdfs/Publications/ClimateWise/SLOModelReport_FINALsmall.pdf).

Scientists at the GEOS Institute explored potential future climate conditions in San Luis Obispo County using three global climate models – CSIRO, MIROC, and HadCM[1] under the A2 emissions scenario. Output was converted to the locally-relevant scale of 8km by the USDA Forest Service MAPSS team at the Pacific Northwest Research Station. Climate models rely on equations describing physical relationships in the atmosphere, land surface, cryosphere (ice and snow), and oceans to project future conditions. The Intergovernmental Panel on Climate Change (the leading scientific organization assessing climate change and the risks to environmental and socioeconomic resources) tested the ability of these three models, and many others, to accurately reflect historical climate patterns and conditions. The MAPSS team selected CSIRO, MIROC, and HadCM from the suite of available models because their outputs are readily usable for the MC1 vegetation model, which provided us with projections for such variables as growing conditions for dominant types of vegetation, wildfire, and carbon storage in biomass. While model projections will always encompass uncertainty (models are simplified representations of complex processes) they are the best available tools for assessing future conditions, thus allowing us to identify risks, develop adaptation strategies, and build plans based on potential future scenarios. As actual trajectories are revealed and new approaches are developed, plans will need to be revisited and revised in an adaptive management context to best reflect new information.

[1] For a thorough description of the global climate models and their assumptions, see Randall et al. 2007.

CLIMATE CHANGE IN SAN LUIS OBISPO COUNTY

Climate change is a global phenomenon that has the potential for severe local impacts to agriculture, human health, natural resources, infrastructure, emergency response needs, tourism, and many other facets of society. Climate change impacts are expected to exacerbate the vulnerability of certain populations and sectors of society. By identifying and addressing underlying vulnerabilities early, decision makers in San Luis Obispo can increase the resilience of the community, and the resources it depends on, to climate change.

Possible changes by the end of the century:

- hotter, drier, and longer summers
- less warming in western county compared to eastern county
- more severe storms in winter/spring
- accelerating sea level rise
- loss of coastal wetlands, marshes, and estuaries
- declines in water availability and water quality for streams and rivers
- lower groundwater recharge rates
- loss of native species and ecosystems
- loss of many pine forests
- increase in wildfire by 200-300%
- lower productivity of range for cattle
- increase in invasive species

The climate change model outputs in this report were obtained from the USDA Forest Service Pacific Northwest Research Station and analyzed and mapped by scientists at the GEOS Institute (Koopman et al. 2010). We present the results from three global climate models (HadCM, MIROC, and CSIRO) that come from a suite of models reviewed by the IPCC. These three models, as well as a vegetation model (MC1), were run using the A2 ("business-as-usual") emissions scenario and reported at a scale of 8km. **Because of emissions already released in the atmosphere, the mid-century projections in this report are likely to be realized, but late-century conditions may be quite different from those presented if emissions deviate from the "business-as-usual" scenario.** A companion report (see link on page 10) provides more in-depth coverage of climate change model assumptions, emissions scenarios, uncertainty, and projections for San Luis Obispo County.

The three global climate models used in this report provide us with a possible range of future conditions. Actual conditions may differ from those presented here. If climate change progresses more quickly than expected, for example, some changes could be more severe or rapid. Additionally, as models are refined and updated, projections for future conditions could change considerably. Luckily, precisely predicting future conditions is not necessary for implementing sound strategies that reduce local vulnerabilities. For instance, most models predict drier conditions, on average, along the central coast of California. Planning for more frequent and severe drought

is considered a "no-regrets" strategy because drought already occurs on a regular basis and, as the population continues to grow, increased resilience in the face of drought would benefit San Luis Obispo, regardless of climate change. Similarly, floods are expected to become more common as storm systems increase in severity. Reducing the vulnerability of the county's systems (dams, agriculture, etc.) to flooding provides many benefits, including saving money and lives. While climate change is the impetus for this effort, the strategies recommended in this report benefit residents of San Luis Obispo County in a variety of ways, regardless of the precise trajectory of the changing climate.

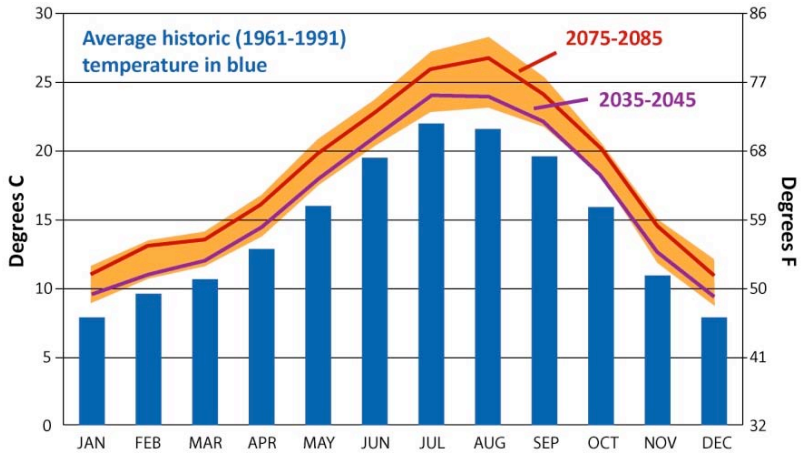
Local Climate Change Projections

Temperature – According to the three global climate models used in this analysis, San Luis Obispo County is expected to become 2-4° F warmer by mid-century and, depending on emissions, 4-8° F warmer by late-century, with greater warming in summer as compared to winter (Table 1; Figure 2).

Table 1. Projected increase in average temperature in San Luis Obispo County, from three different global climate models, compared to the historic average temperature from 1961-1990, assuming "business-as-usual" emissions.

TEMPERATURE	2035-2045	2075-2085
Annual	+2.1 to +3.9° F (+1.2 to +2.2° C)	+4.1 to +7.6° F (+2.3 to +4.2° C)
Jun - Aug	+1.8 to +4.7° F (+1.0 to +2.6° C)	+4.3 to +8.9° F (+1.0 to +2.6° C)
Dec - Feb	+1.7 to +3.6° F (+1.0 to +2.0° C)	+3.4 to +7.0° F (+1.9 to +3.9° C)

Figure 2. Average monthly temperature across San Luis Obispo County. Future projections are averaged across the three global climate models for two different time periods: 2035-45 (purple line) and 2075-85 (red line). The full range of projections from all three models is shown in orange.



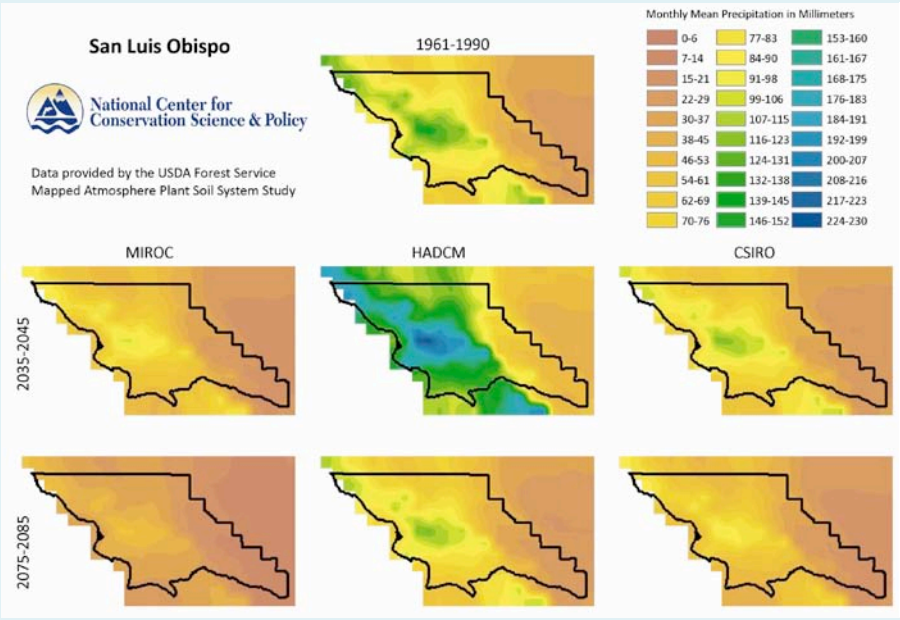


Figure 3. Average January precipitation, in millimeters, across San Luis Obispo County – historically (top) and projected for 2035-45 (middle row) and 2075-85 (bottom row). Projections are based on three different global climate models (MIROC, HadCM, and CSIRO).

Precipitation – Model projections for precipitation were highly variable. On average, little change in precipitation was projected, except in the winter (Figure 3). One model projects an increase in precipitation by mid-century (2035-45). By late century (2075-85), all three models agree on drier conditions for San Luis Obispo County.

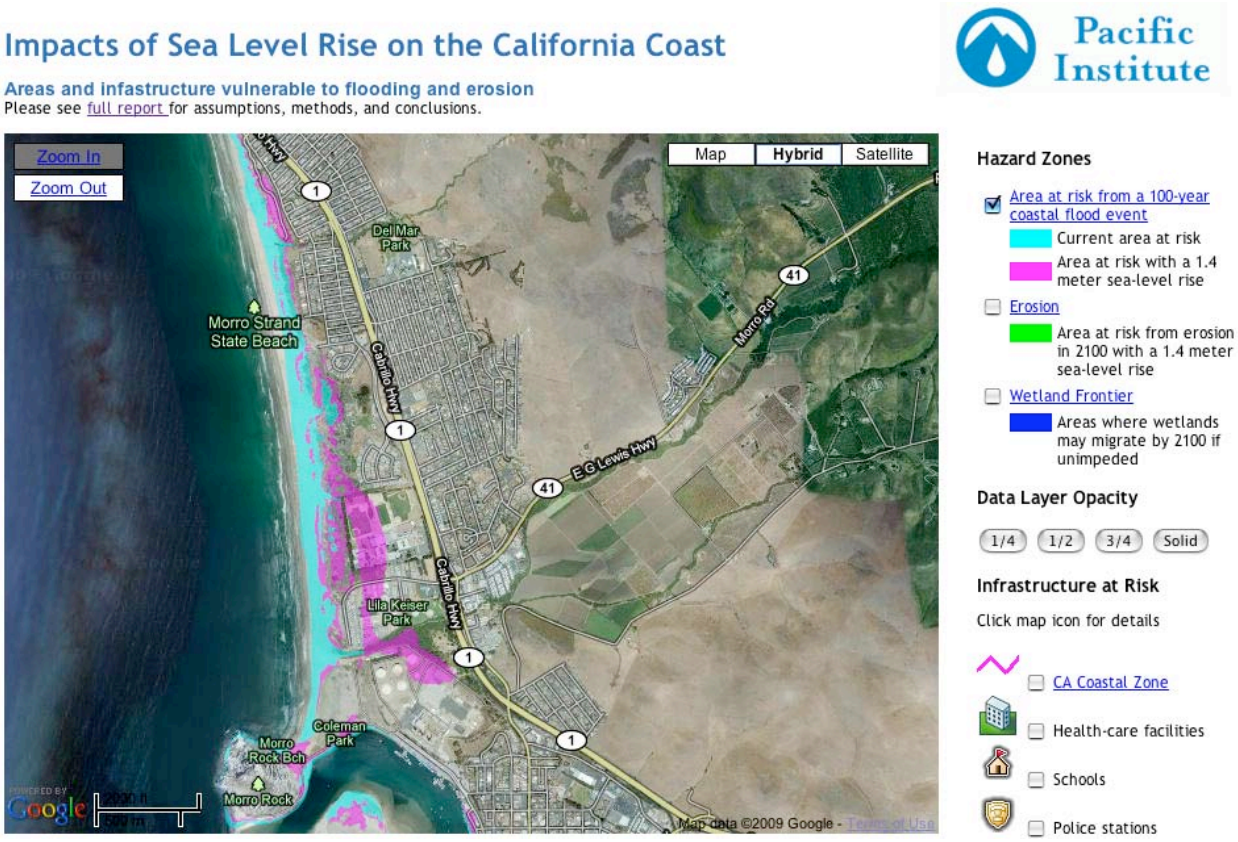
Sea-level rise – In a report commissioned for the California Energy Commission, Cayan et al. (2009) indicate that by the end of the century, sea level is expected to rise 3.3 – 4.6 feet (1.0 – 1.4 meters) based on projections from six different global climate models run under the same A2 "business-as-usual" emissions scenario used in this report. Sea-level rise could accelerate even more, however, due to melting ice sheets. Sea level rise will cause erosion along the coast as well as increased risk of damaging floods during large storms. Additionally, sea level rise causes saltwater intrusion into wells and freshwater ecosystems near the coast.

Vegetation change – A vegetation model (MC1) from the USDA Forest Service's Pacific Northwest Research Station projects future growing conditions and wildfire patterns for San Luis Obispo County. Future growing conditions help us identify the type of vegetation that the climate is most suitable for, but they do not take into account non-native vegetation, seed dispersal, or succession (the time needed for climax tree species, for instance, to mature and dominate the landscape), as well as human use of the landscape. The MC1 model projects a loss of conditions for coniferous forest at higher elevations and shifts in types of vegetation throughout eastern portions of the county. Western portions may remain more stable.

Wildfire – Northern and northeastern parts of the county, especially areas of higher elevation, could see increases

in the area burned annually by wildfire due to higher temperatures and stress to vegetation from climate change. On average, San Luis Obispo County could experience 2-3 times greater area burned by wildfire, annually, by the end of the century.

Storm events – Climate change could increase the severity of individual storm events, even if overall precipitation levels do not increase. When more rain falls during a single storm, the risk of flooding is greatly increased. Such storm events can be exacerbated by land use practices and infrastructure failures, making the impacts of flooding more severe. When rainfall occurs in a short period of time, most water runs off quickly without infiltrating soils or recharging groundwater aquifers.



An example of areas identified by the Pacific Institute as at-risk from climate change (see Heberger et al. 2009).

BOTH ADAPTATION AND MITIGATION ARE VITAL

The impacts outlined in the previous section are expected to increase in severity over the next century and beyond, depending on emissions. Greenhouse gas emissions from today will tie us in to 30 to 50 years of increasingly severe impacts, but drastic reductions in emissions could reduce late-century impacts. Two primary approaches to climate change have been adopted – adaptation and mitigation. **Adaptation efforts increase the resilience of communities and resources to near-term climate change impacts. Mitigation efforts aim to reduce the long-term severity of climate change by lowering the concentration of greenhouse gases in the atmosphere.** Adaptation measures can be effective in the near term but will fail over longer time scales without effective mitigation.

There are many ways that mitigation and adaptation can work hand-in-hand. For example, restoring floodplains is expected to result in a lower risk of floods to local communities (adaptation), increased groundwater recharge (adaptation), and prevention of the need for energy intensive desalinization (mitigation). In other cases, adaptation and mitigation can undermine each other or other policy goals. Thus, when strategies are developed, the consequences for mitigation, adaptation, and other policy goals will always need to be weighed so that unintended conflicts can be avoided.

In addition to integrating climate change mitigation and adaptation, individual strategies for adaptation can be integrated across different sectors, often with cost savings and other positive synergies. For example, strategies that reduce flood risk to vulnerable populations can also increase groundwater recharge, thereby benefitting agricultural producers. Similar efforts can also be designed to improve aquatic species habitat and water quality. In order to develop strategies that have benefits across many sectors, communication and collaboration across sectors is mandatory. **Such collaboration is expected to reduce overall costs, increase success of individual strategies, and lead to a "team" effort rather than competition for limited funding and resources.** Regular communication among such disparate groups as farmers, ranchers, state and federal agencies, Native Americans, public health professionals, county planners, social services, land, water, and wildlife managers, and many others, is vital for developing cohesive, effective, and efficient strategies.

Climate change is like an imminent car crash.

Mitigation is the brakes – it will reduce the magnitude of the impact of climate change.

Adaptation is the airbags – it will soften the blow.

We need BOTH mitigation and adaptation to survive the crash intact.

THE ROLE OF THE STATE

California is particularly vulnerable to the potential impacts of climate change. Projected increases in temperature and precipitation changes, increased transmission of infectious diseases, and higher air pollution levels could significantly impact public health and mortality rates. California's coastline communities and wetlands could suffer extensive and irreversible damage as sea levels rise over the next century, with over $200 billion in infrastructure at risk (Heberger et al. 2009). The state's $30 billion agriculture industry could be disrupted by changes in temperature and rainfall patterns and the increased pests and diseases that may accompany those changes. California's water supply is already facing challenges, yet a projected loss of 80% of the state's snowpack by 2100 (Hayhoe et al. 2004) could have disastrous consequences.

Due to the severity of potential impacts, the state has taken action to combat climate change through legislation including the Global Warming Solutions Act (AB 32) and Sustainable Communities and Climate Protection Act (SB375).

State officials have identified transportation as the largest single source of greenhouse gas emissions, with 38% emitted by all modes of transportation (cars, light and heavy duty trucks, rail and water). The energy sector is the second-largest source of emissions. Because both sources are significantly influenced by local government land use decisions, local government officials have both the opportunity and the enormous responsibility of playing a key role in achieving the state's greenhouse gas reduction targets. The box above provides descriptions of these key pieces of climate change legislation as they relate to local governments.

Statewide Legislation

AB32 – Directs the California Air Resources Board (CARB) to reduce the State's global warming emissions to 1990 levels by 2020 and 80% below 1990 levels by 2050. CARB completed a Scoping Plan, which will become enforceable in 2012. State agencies and local governments will be responsible for implementation.

SB375 – Fosters coordination between regional transportation planning processes and local government strategies to reduce greenhouse gases from transportation. The bill sets a framework for meeting regional greenhouse gas reduction targets through land use changes and other local policies. Regional transportation plans will be required to include a Sustainable Communities Strategy (SCS) or develop an Alternative Planning Strategy (APS) that identifies barriers to meeting greenhouse gas reduction targets.

2010 California Green Building Standards Code (CALGreen) – Sets mandatory requirements for new residential and nonresidential buildings throughout California taking effect on January 1, 2011. CALGreen was established to reduce construction waste, make buildings more efficient in the use of materials and energy, and reduce environmental impact.

In 2008, Governor Schwarzenegger signed an Executive Order (S-13-08) asking the Natural Resources Agency to identify how state agencies can respond to rising temperatures, changing precipitation patterns, sea level rise, and extreme natural events. The California Natural Resources Agency in collaboration with multiple state agencies developed the 2009 California Climate Adaptation Strategy (available at http:/www/climate change.ca.gov/adaptation/). The report summarizes the best-known science on climate change impacts and provides recommendations on how to manage and reduce those threats. The California Climate Adaptation Strategy focuses on sectors that include: Public Health, Biodiversity and Habitat, Ocean and Coastal Resources, Water Management, Agriculture, Forestry, and Transportation and Energy Infrastructure.

THE ROLE OF LOCAL GOVERNMENTS

The San Luis Obispo region has emerged as a leader in the state by taking extensive measures to reduce their greenhouse gas (GHG) emissions. The County of San Luis Obispo and the City of San Luis Obispo have both completed GHG emissions inventories and are preparing climate action plans (CAPs) through federal Energy Efficiency and Conservation Block Grants. The County recently adopted the Conservation and Open Space Element (COSE) of its general plan. The COSE includes goals, policies, and implementation strategies that address climate change, energy efficiency and conservation, and water conservation among other resource conservation topics. The cities of Atascadero, Arroyo Grande, Grover Beach, Morro Bay, Paso Robles, and Pismo Beach prepared baseline inventories of GHG emissions from community-wide and government operations through funding from the San Luis Obispo Air Pollution Control District.

All of the cities in the county, the County, the San Luis Obispo Air Pollution Control District and San Luis Obispo Council of Governments are also working together through multiple programs to improve the sustainability of the region and to address climate change. Local and regional programs address energy use (including developing a renewable energy/energy efficiency-financing district), encourage bicycling and walking, stimulate green jobs, and promote green building. In addition, local agencies are collaborating to pursue grant resources for climate action planning and public outreach as appropriate.

These efforts are a great step towards improving the sustainability of the region. The County and the cities within have the additional opportunity to address climate change adaptation by integrating the appropriate strategies developed through this process into current and ongoing planning efforts.

VULNERABILITY IN NATURAL AND SOCIOECONOMIC SYSTEMS

Groups of experts and local leaders were convened at a series of workshops in San Luis Obispo County. The first workshop focused on natural systems while the second focused on socioeconomic systems. The following two were used to integrate and refine adaptation strategies across all sectors. Participants represented different sectors of society, and were tasked with identifying what resources and populations might be most vulnerable to climate change in light of concurrent stresses. They also developed initial strategies that could be implemented to benefit communities immediately and reduce the impacts of climate change in the future. Represented sectors include (1) Public Health and Emergency Preparedness, (2) Agriculture and Related Tourism, (3) Water, (4) Infrastructure, (5) Coastal and Marine Resources and Related Tourism, and (6) Species, Ecosystems, and Ecosystem Services.

Prior to the workshops, Susanne Moser Research and Consulting completed a qualitative social vulnerability assessment for Fresno County (see Moser and Ekstrom 2010, accessed at http://www.lgc.org/adaptation/slo/). Using data from the U.S. Census about demographics and economics, emergency response and preparedness systems, public health, general plans and associate planning documents, and existing flood, fire, and other hazard risks, they examined the three components of vulnerability to climate change: exposure, sensitivity, and adaptive capacity. Together these components help reveal areas, populations, economic industries and other aspects of the region's social systems that are most vulnerable to climate change (IPCC 2007). Workshop participants considered the components of vulnerability as they developed adaptation strategies.

Larry Allen from the APCD participated in the section on health and emergency preparedness.

Exposure is the nature and degree to which a system experiences a stress or hazard.
Sensitivity is the degree to which the system is impacted by a given stressor, change or disturbance.
Adaptive capacity *refers to* ability to cope with extreme events, to make adaptive changes, or to transform more deeply, including the ability to moderate potential damages and to take advantage of opportunities.

Climate change will most impact those individuals and systems that have both the greatest **exposure** and **sensitivity** to climate change impacts, in addition to the lowest **adaptive capacity** (Table 2). For each climatic

hazard, which population and which economic sector is most vulnerable depend on the unique combination of these three factors. For example, in the case of extreme heat, some of the most vulnerable populations include: the elderly, infants, and outdoor workers (especially in the hotter inland areas). These groups experience greater exposure and sensitivity and generally have a lower capacity to adapt to the impacts of climate change (Moser and Ekstrom 2010). Similarly, institutionalized populations (e.g., in colleges or prison) are of special concern due to their location in flood, landslide and fire risk zones, and the challenge of evacuating large numbers of people in short periods (Moser and Ekstrom 2010). In many instances, a growing and aging population will exacerbate existing challenges, while economic prosperity and well-functioning infrastructure, governance and social networks could reduce vulnerabilities.

While species and ecosystems are vulnerable in much the same way as socioeconomic systems, we used a different approach to identify vulnerable areas, species, and ecosystem functions across San Luis Obispo County. We gathered together local natural systems experts and asked them to identify the regions, species, and functions at greatest risk from climate change as well as from population growth and land use stressors.

Table 2. Examples of climate-related extreme events interacting with the three components of climate change vulnerability (adapted from Moser and Ekstrom 2010).

Components of Vulnerability	Climatic Risks	Populations or Infrastructure Particularly At Risk
Exposure	Floods	Floodplain residents
	Heat	Outdoor workers
	Drought	Farmers, all water users
	Wildfire	Homes at the wildland-urban interface
Sensitivity	Heat	Infants, elderly
	Air pollution	Asthma sufferers, children
	Drought	Farmers
Adaptive Capacity	Floods	Institutionalized populations, low-income households
	Heat	Low-income residents
	Sea-level rise	Coastal residents, structures and facilities

LOCAL VULNERABILITIES, IMPACTS, AND RECOMMENDED ADAPTATION STRATEGIES

Climate change will impact San Luis Obispo in a variety of ways, some potentially severe, with direct impacts on its people, economic sectors, its supporting infrastructure and services, as well as the natural environment on which much of the county's economy, rural character, and quality of life depends. The impacts to these sectors will differ based on current and future vulnerabilities to weather- and climate-related changes and extreme events in San Luis Obispo County.

The vulnerability assessment (Moser and Ekstrom 2010) revealed the following critical vulnerabilities:

- Differential social vulnerabilities, with the **elderly, infants, socially and culturally isolated individuals, and outdoor workers** – especially in the hotter inland areas – experiencing relatively greater exposure, sensitivity and/or lower adaptive capacity.
- Social vulnerabilities vary with regard to different climate-related hazards. A **growing and aging population** will exacerbate the challenges, while economic prosperity and well-functioning social networks could reduce these vulnerabilities.

Photo courtesy of Wikimedia Commons

- Several **institutionalized populations** are of special concern due to their location in flood, landslide and fire risk zones (college, prison), and the challenge of evacuating large numbers of people in short periods.
- **Coastal residents** are particularly vulnerable to sea-level rise and related hazards such as flooding, erosion and cliff failure. Many coastal residents are elderly and depend on transportation (and evacuation) routes that are at risk from erosion, flooding, wildfires, and landslides.
- Crucial **supporting infrastructure and services** will experience greater demands or challenges as climate change-related risks grow, including for already scarce water supplies, transportation and energy infrastructure, and emergency preparedness and services.
- Water supply shortages, which are already a serious problem, are expected to worsen. **Residents in rural areas that depend on groundwater alone and farming that relies on groundwater and/or state water allocations** are especially vulnerable.

1. Public Health and Emergency Preparedness

Potential Impacts:

Heat related mortality and hospitalizations are expected to increase. Outdoor workers, elderly populations, and infants are most vulnerable to extreme temperatures.

Respiratory and cardiovascular disease may increase. Model projections indicate a potential increase in wildfire, which could lead to declines in air quality. Additionally, ozone is expected to increase with higher temperatures and plants may produce more allergens with higher levels of CO_2 in the atmosphere.

For low-income populations, food security may decline. Local food production is likely to be impacted by extreme weather events, higher temperatures, and less water availability for agricultural production, resulting in lower local production unless the industry expands. This could have negative health consequences.

A greater burden on and higher demand for emergency and social services could result if more frequent or severe natural disasters occur. If the frequency or severity of floods and fires increases, we can expect increased rates of stress-induced mental health issues (Moser and Ekstrom 2010).

Picture from San Luis Obispo County Fire Department webpage

Recommended Strategies:

Make expanded outreach and education on emergency preparedness a top priority. Potential strategies include preparing the public through:

- training exercises
- information on emergency exit routes and methods
- an effective outreach campaign to increase personal preparedness
- citizen emergency response training
- incorporating emergency response education into school curriculum

Identify and target vulnerable populations for outreach. Other strategies to educate and outreach on emergency preparedness include partnering with local businesses for funding and having emergency communication mechanisms available during disasters. Cultural and linguistic needs should always be considered when providing information.

Implement strategies to bolster wildfire management planning in the region. Wildfire management planning is a top priority for both the health and emergency preparedness sectors. Some initial strategies include:

- streamlining fire management regulations
- enhancing controlled burning and management
- promoting mechanical fuel management versus burning
- streamlining permitting for fuel management
- creating defensible space around key structures
- consolidating fire agencies
- amending the state budget to allocate funding for fuel management

Increase local food production and security while reducing vehicle miles associated with food delivery. The county and cities within can do this by:

- designating sites for community gardens and farmers' markets
- enacting ordinances to allow chickens and home gardens
- implementing policies for efficient land use and farm land conservation
- educating the public (shoppers) on the benefits of buying locally produced food
- providing incentives like "Lawn to Garden" or "Food Forest" programs
- lobbying school districts and other local institutions (e.g., state hospitals, prisons and other state agencies) to primarily buy locally produced food

Promote healthy lifestyle practices through new policies and strategies. Cities and the county should implement land use polices to promote bicycling and walking which that will help to improve health (thereby increasing the ability to withstand health related climate stressors) and to help mitigate the effects of climate change by reducing vehicles miles traveled. Incentives should be offered to attract additional medical personnel to the area and retain existing providers. Stakeholders also emphasized the need for localized urgent care.

2. Agriculture

Agriculture generates significant value for the county. It also is the predominant land use, with over 55% of land zoned for agriculture. The highest ranked crops by dollar amount are grapes/wine, broccoli, strawberries and cattle/calves.

Potential Impacts:

Climate change-related threats to agriculture in San Luis Obispo County include:

- higher temperatures, causing heat stress to plants
- reduced water availability
- potential for increased water costs
- more intense downpours, leading to fruit, vegetable and flower damage
- increased risk of soil erosion
- increased water demand by plants and animals
- increased risk of pest infestations and spread of invasive plants

The ability for farmers and farm workers to deal with climatic changes depends on a number of factors. In general, smaller farmers with fewer financial, technological, and water resources, and farmers with fewer or less flexible response options, limited crop diversity, fewer risk sharing opportunities, and greater dependence on farm income tend to be more vulnerable to climate change. Outdoor workers in farming, especially in hotter inland areas, are more exposed to extreme heat than indoor workers. They have little incentive or opportunity to seek shade, rest, rehydrate, or avoid exposure altogether and are therefore particularly at risk (Moser and Ekstrom 2010).

The county's agriculturally based tourism (largely wine-related) may suffer if climate change causes large enough shifts in the wine industry. Visitors' perceptions of reduced attractiveness of the region such as lower wine quantity and quality, loss of beautiful natural areas, and increased risk from wildfires – combined with broader, more remote socioeconomic changes (e.g., higher transportation costs) – may be as or more important than the direct impacts from climate change.

The Northern Chumash[2]

The Chumash have inhabited San Luis Obispo County for more than 20,000 years. They experienced the last glacial maximum, with sea levels 300 feet lower than today and vegetation characterized by giant redwoods and oaks. Modern Chumash are determined to become as resilient and self-reliant as their ancestors. The Northern Chumash Tribal Council is working towards self-reliance through organic agriculture and local businesses. They operate an all-natural farm using greenhouse aeroponics – an approach to farming that uses only 10% of the land and water of typical farms.

[2] Information provided by Fred Collins, Tribal Spokesperson and www.northernchumash.org

Recommended Strategies:


Wikimedia Commons

Make water conservation a top priority for agriculture in the region. The region's farmers have already made strides towards conserving water. Unfortunately, water is expected to become even more scarce, making additional efforts necessary. By conserving water farmers can adapt to climate change impacts (less water availability) and save money. The county and cities should work with California Polytechnic State University (Cal Poly) and the University of California Cooperative Extension (UCCE) to develop and promote best management practices and new technologies. Policies and programs to encourage recycled water should also be implemented.

Reduce greenhouse gas emissions associated with agriculture and increase carbon sequestration in soils. Policies to encourage local food production and purchasing will decrease "food miles traveled" and increase the market for locally produced foods, keeping more land available for carbon storage. Organic farming should be encouraged. Farming practices such as "no till" are also effective ways to store additional carbon in farmland soils. Encouraging energy efficiency on farms, packing sheds, and in processing will reduce costs and contribute to climate change mitigation. Policies to encourage tree planting and to enhance forestry and riparian management on agricultural lands should also be implemented.

Develop new tools and economic incentives that lead to conservation of agricultural land. If water resources become more expensive or production is lowered from storms or drought, many agricultural producers could be tempted to sell their land to developers. Potential approaches to conservation include land banks and conservation easements. The Williamson Act (California Land Conservation Act of 1965) should be maintained as one of the key tools communities have to preserve farmland. Local jurisdictions should work with Cal Poly and UCCE to identify new tools with increased flexibility. Tools and incentives should take into consideration habitat connectivity for plants and wildlife.

Provide support for farm workers and employees of the agricultural tourism industry as the climate changes. Local jurisdictions should work with organizations like the Farm Bureau, Farm Supply and UCCE to provide educational workshops to educate farmers about the potential impacts of climate change, identify on-farm adaptation options, address social injustices and minimize conflicts, housing shortages and direct heat-related impacts for farm/tourism workers. Affordable housing should be provided to workers on-site or nearby. More stringent efforts to implement measures to prevent heat-related risks to workers should be established, monitored and enforced.

3. Water Resources and Infrastructure

Because agriculture is one of the region's major sectors and water users, water availability, use, storage, and delivery is a priority concern.

Potential Impacts:

Water supply shortages, which are already a serious problem, are expected to worsen. Climatic conditions are expected to be drier, with longer, hotter summers, and the water supply from the Sierras is expected to decline. Higher temperatures and continued population growth suggest there will be a growing demand for water while supplies are shrinking. This affects the entire county, but especially residents in rural areas that depend on groundwater alone and farming that relies on groundwater and/or state water allocations.

Climate change could also cause reduced groundwater recharge. The region may see more severe (but not more frequent) rainfall events, leading to quick pulses of runoff. Currently, there is insufficient infrastructure to harness that momentary surplus of water, and poor land use practices prevent much of the rain from infiltrating into the ground.

Saltwater intrusion into coastal aquifers with shallow water tables will worsen with sea level rise. The county already experiences saltwater intrusion in several areas along the coast (e.g., Los Osos and Oceana). This is the result of historical sea-level rise combined with over pumping of groundwater.

Septic systems and sewage treatment plants could be compromised by climate change. Increases in intense rainfall events and associated runoff could impede the proper functioning of the county's many onsite septic systems or overwhelm sewers and centralized sewage treatment plants. As a result, untreated water, with the full load of toxics and organic waste, could enter streams and coastal waters.

Salinas River near San Ardo Oil Field; photo courtesy of Wikimedia Commons

Recommended Strategies:

Implement new policies and programs to monitor water use and encourage agricultural producers to use water more efficiently. Financial incentives may need to be provided in some situations. Cities, Community Service Districts and the County should work with water agencies, mutual water companies and regional planning agencies to monitor and reduce agricultural water use. Some collection of stream flow and water quality data will need to be collected on private land – whether to make such data public will need to be discussed with land owners.

Enforce the Clean Water Act. Limits on pharmaceuticals in wastewater discharge/recharge should be enforced to improve water quality and safety. Pharmaceuticals that aren't disposed of properly are ending up in streams and groundwater, exposing local water consumers. Changes to aquatic organisms have been noted and low levels of pharmaceuticals may be the cause. Monitoring to detect pesticides and herbicides in runoff should also be conducted.

Integrate planning across jurisdictions by increasing collaboration and communication. Planners will need to collaboratively address water supply threats, flooding, and wastewater management. Strategies should include developing programs and policies to preserve watersheds and implement groundwater management ordinances to assure a long-term, sustainable, reliable, good quality groundwater supply.

Encourage low impact development, natural filtration, and urban runoff catchments. Stormwater management policies and programs will be increasingly important as the region faces additional rainfall events.

Additional strategies should be considered (where appropriate) such as:

- use recycled water
- encourage greywater systems for use in outdoor watering
- consider desalination as a last order option due to increased energy use and costs required
- develop constructed wetlands to improve recharge and water quality
- build reclamation water plants (for parks, golf courses, etc.)
- reduce the use of ocean outfalls (that discharge wastewater to the sea)
- increase recharge into groundwater basins
- reduce sedimentation of streams and rivers by changing land use practices

Newly constructed wetlands; photo courtesy of Wikimedia Commons

4. Infrastructure

In support of people's daily life, well being, safety, travel and participation in San Luis Obispo County's economic and recreational activities, the county provides a variety of infrastructure and community services. Many of them are susceptible to climate change, both directly and indirectly.

Potential Impacts:

Transportation routes are exposed to several climate change impacts. Sea-level rise and related flooding, erosion, cliff failures, heat extremes, inland flooding, and increased wildfire and associated problems with soil erosion and landslides, are all expected to stress transportation routes. The Pacific Institute estimated 28 miles of roads in the county would be affected by sea-level rise (Heberger et al. 2009). Areas of particular exposure to sea level rise (and associated storms/waves) are Highway 1 and possibly 101 at Pismo Beach, Highway 1 at Cayucos, and several areas of the same highway in and north of Cambria and San Simeon. Several of the latter portions of highway are already vulnerable to flooding, which would be exacerbated by sea-level rise unless the road is relocated. Some communities have few alternative escape routes in the case of an emergency, such as a wildfire or landslide, and associated closure of major roads.

The Diablo Canyon Nuclear Power Plant is exposed to the impacts of climate change. The plant and the infrastructure upon which it depends are directly exposed to the impacts of coastal storms, flooding and erosion, which will be exacerbated by sea-level rise. The plant is located directly along the shoreline and uses seawater for cooling, but it is highly fortified by sea walls.

Diablo Nuclear Power Plant in spring; photo courtesy of Jim Zimmerlin

Recommended Strategies:

Work with the private sector to achieve smart growth policies and avoid building in areas at risk under climate change projections. Smart land use planning will reduce the effects of climate change by reducing vehicle miles traveled and reducing demand for at risk and over burdened transportation infrastructure. The cities, County and the Council of Governments should implement smart land use policies that:

- encourage compact, mixed-use development
- improve job-housing connectivity
- incentivize living close to work
- encourage transit-oriented development
- price parking appropriately
- reduce the heat island effect (urban forestry, landscaping and street trees)
- reduce light pollution
- encourage low-impact design (narrow streets, landscaped swales, rain gardens and groundwater recharge)
- identify and map high risk areas and failing infrastructure to prioritize repairs and improvements (including beach and bluff erosion)

Encourage alternative transportation. Some avenues include increased funding, policy priority, complete streets requirements, requirements for bicycle and pedestrian infrastructure in new developments and locating housing near major urban centers.

Make energy conservation and alternative energy development a priority for the region. Energy use is one of the major contributors to climate change and important energy-related infrastructure is at risk under climate change projections in San Luis Obispo. Local jurisdictions should provide outreach, education, programs and incentives for energy conservation and renewable energy. The county/cities should consider community choice aggregation (basically becoming their own energy distributor) to purchase electricity and increase the amount of non-polluting, renewable energy available to residents.

Energy programs that local jurisdictions could take advantage of and promote to the public include:

- energy efficiency and conservation block grants
- utility programs
- incentives for alternative vehicle fuels and infrastructure
- Property assessed clean energy (PACE) programs, which enable local governments to finance renewable energy and energy efficiency projects on private property, including residential, commercial, and industrial properties
- Home Star Act of 2010, a two-year federal program that would provide direct consumer incentives for residential efficiency retrofits

5. Coastal and Marine Resources and Related Tourism

Potential Impacts:

Fisheries, harbors and coastal tourism make up important economies of the county that are threatened by climate change. Climate change is expected to impact fish populations directly through warming ocean waters, increasing ocean acidity, changing currents and nutrient availability, and inundation of critical nursery habitat (coastal wetlands). Ocean acidification is expected to also severely impact shellfish fisheries and aquaculture.

Coastal storms can cause coastal flooding of low-lying areas – inundating economically important infrastructure such as the harbors of Morro Bay and Port San Luis. **The erosive impact of storms could also cause severe damage to coastal developments and facilities**. Both of these coastal hazards are expected to become greater threats to coastal areas as sea level rises.

Beach erosion will increase in many areas and may require more frequent sand replenishment. Other coastal areas may see more sediment. The county's coastal tourism relies on clean and beautiful beaches, scenic vistas and drives, and birds, wildlife and fish for recreation..

Tourism infrastructure, such as roads, buildings, harbors and piers could be damaged by higher sea levels and coastal storms. Tourism requires functional infrastructure, services and establishments, such as coastal roads, hotels, restaurants and guided tours, to support the industry.

Recommended Strategies:

Identify high-risk areas and map failing infrastructure to prioritize repairs and improvements. Local governments in San Luis Obispo are faced with tough choices to protect, repair and upgrade or even relocate critical infrastructure. Limited resources necessitate calculated decision-making. Local jurisdictions should plan alternate escape routes for emergency evacuations.

Coastal land use policies should be reassessed. The County and FEMA should update flood zones with consideration of sea-level rise and potential extreme rainfall events. Local jurisdictions should implement polices (zoning and building codes) to discourage building and repairs in high-hazard flood and erosion zones.

Species migration corridors, destinations and adjacent habitat should be protected. New policies for existing and new development will need to account for growing coastal hazards (National Estuary Program), identifying key habitat and providing tax incentives to preserve habitat and resist offshore oil drilling.

Increase monitoring and research of ocean acidification process and effects.

Develop and promote ecotourism and other strategies to draw visitors in ways that boost local business, minimize impacts to natural resources, and build environmental awareness.

6. Species, Ecosystems, and Ecosystem Services

As climate change progresses, fish, wildlife, and plants are expected to respond in many ways. Most species' distributions will shift (possibly moving northward or upslope, but sometimes moving in unexpected directions due to changes to prey, predators, or other habitat features) to track suitable climate conditions. In order for many species to disperse to new areas, current and future habitat must be available and connected. Some species will be unable to move, and changing conditions will cause declines, local extirpations, and even extinction; by the end of the century, 30% of all species could go extinct (Thomas et al. 2004). Yet San Luis Obispo County has the potential to retain higher native species diversity than most other parts of California (Loarie et al. 2008) due to coastal influences on the climate and topographic complexity. While native and endemic species are likely to decline with climate change, many invasive non-native species could expand their ranges.

"Ecosystem Services," also called **"Nature's Benefits,"** refers to services or products that we gain value from in the form of intact, functional, ecosystems. In San Luis Obispo, some important activities dependent on ecosystem services include:

Recreation/Tourism	**Water**	**Agriculture/timber**
Fishing	Flood abatement	Pollination
Bird watching	Groundwater recharge	Soil stability
Hiking/Mountain biking	Sediment filtration	Cattle grazing
Kayaking	Water storage	Timber or firewood
Wine country touring	Hydroelectricity	Aquaculture
Camping	Removal of pollutants from waterways	Carbon storage

San Joaquin kit fox
Photo courtesy of Brian Cypher

Coastal and Nearshore Marine Ecosystems

Potential Impacts:
Based on climate change model projections for San Luis Obispo County, local experts identified the following as the most important potential impacts in the county:

Sedimentation is likely to increase in marshes, estuaries, and coastal streams. Potential increases in fire and severe storms could exacerbate already high rates of sediment runoff. This would lead to shallower, warmer water, with complete loss of some estuaries due to sedimentation combined with sea level rise. The Salinas River and Morro Bay were both identified as at-risk.

Coastal birds may decline in number. Sea level rise is expected to cause inundation of coastal marshes and wetlands – important water bird and shorebird habitats. Many species, including snowy plovers, least terns, brown pelicans, and brant, are expected to lose habitat (rocky intertidal or dune) and food resources (fish, eel grass, etc.). The Four Dune area was identified as at-risk. Bird related tourism may also decline.

Salt water is likely to intrude into estuaries, creeks, and wells along the coast. Aquatic and riparian wildlife are expected to be impacted, as well as people in the region, especially in the Chorro Creek, Los Osos area, and the Arroyo Grande watershed. Flooding could occur in these areas as well as Grover Beach (behind dunes in coastal plain), the Santa Maria River, and Diablo Canyon. Willow habitats are threatened by salt water, especially near Pismo.

Rare habitats could decline. Coastal prairie and dune scrub, as well as other important habitats for many endangered species, may decline from changes in temperature, precipitation, and salinity. Species that are isolated (due to development in surrounding areas) are especially at risk from climate change due the lack of opportunity for shifts in their distribution. Sea blight, salt marsh bird speak, Morro shoulderband snail and Chorro shoulderband snail are at increased risk from climate change.

Marine and nearshore marine species are threatened by acidification of ocean waters and changes in ocean currents. At risk are the fringing reef in front of Montana de Oro and Morro Bay eelgrass, in addition to many other near shore areas. Sea lions may become more susceptible to disease with higher temperatures and reduced water quality.

Changes in fog could lead to loss of elfin forests (coastal oak forests). Other fog-dependent species would also be at risk.

Recommended Strategies:

Improvements to land management practices. Measures that reduce sedimentation, thereby reducing the impacts to marshes and estuaries would be beneficial to wildlife. Such an effort would also improve water quality in streams and rivers. Land use practices that allow water to slowly absorb into the ground would not only reduce sedimentation, but also increase groundwater recharge. Some examples include:

- reducing soil impaction from cattle
- fencing riparian areas from cattle
- leaving more vegetation on the ground after harvest or other treatments
- maintaining residual dry matter
- maintaining a substantial buffer of riparian vegetation bordering streams, ditches, and rivers, that connects to intact upland habitats
- planting native grasses that have long root systems for soil stability

Areas that are directly upland from dunes, coastal marshes and wetlands should be protected. Important habitats will need to shift as sea level rises. Some potential approaches include:

- City or county purchases of private property
- Rolling conservation easements that shift with the coastline
- Discouragement (by FEMA, state) of rebuilding after floods and storms
- Government support for relocation of structures to less sensitive areas
- Cities and counties plan new structures and facilities with long term view
- Planning that ensures that coastal sewage plants and other facilities meet the Clean Water Act under current and future climate conditions

Current habitat for snowy plovers and other at-risk species should be more effectively and aggressively protected. Many activities currently threaten these habitats, especially development and disturbance. Increased habitat protection may increase the resilience of many species to climate change. The U.S. Fish and Wildlife Service, California Coastal Commission, Point Reyes Bird Observatory, and other entities need to quickly identify critical habitats so they can be protected and buffers and corridors can be planned for climate change.

A county- or state-wide policy on coastal structures may need to be implemented. Such a policy should acknowledge that shorelines are dynamic and take a long-range approach to maintaining important coastal bluffs, dunes, beaches, and other features. A cohesive regional approach would best protect homes and other developments.

New and continuing research should be increasingly supported. Many climate change impacts are unclear. Further research into the sensitivity of eel grass to warming temperatures and changing intertidal conditions, the impacts of increasing acidification on fish populations, and potential changes to fog patterns were all recommended.

Freshwater Aquatic and Riparian Systems

Potential Impacts:

Climate change could exacerbate the impacts of groundwater pumping. Groundwater pumping leads to the lowering of water tables, causing low flows and dry periods in rivers and streams, contraction of riparian areas and wetlands, and stress to aquatic organisms. Because groundwater use by agriculture and local communities is not monitored, a sustainable level of use has not been identified. As climate change progresses, current usage rates would likely lead to increasingly severe negative impacts to aquatic systems.

Sedimentation of streams and rivers may be exacerbated by climate change. Increasing upland wildfire and severe storms may cause increased sediment inputs, thereby reducing water quality and altering substrate. Grazing and other land use contribute to erosion and runoff. The Salinas River has already been impacted by sediment and by ground water pumping. The Salinas Valley is likely to experience continued and exacerbated degradation of riparian habitat due to water use policies and land use conversion. Gravel mining in riparian areas also causes sediment inputs, which can reduce the longevity of local dams and affect water quality.

Climate change may cause higher peak flows (during severe storms) and extended low flows. More extreme flow conditions could have negative impacts on aquatic wildlife. Local communities, such as Paso Robles and the Santa Margarita Ranch, already contribute to lower flows by using river water and ground water for residential and agricultural use. Other areas expected to be impacted include the Salinas watershed, San Juan Creek, Cholame River and Huer Huero Creek.

Many sensitive species are at risk from the combination of current stressors and climate change impacts. Steelhead are very sensitive to weather events, sediment, and stream flow. With worsening conditions, steelhead in San Luis Obispo County could follow the pattern seen in other areas, where spawning no longer occurs. Speckled Dace, an important food item for many birds and other animals, could also be affected.

Lower average rainfall, higher evaporation, and increased sedimentation are expected to have negative impacts on vernal pools, wetlands, and riparian areas. Fairy shrimp, spadefoot toads, two-striped garter snakes, California red legged frogs, pond turtles, and many salamanders are at risk. Tiger salamanders and California red-legged frogs on the San Andreas fault, where they depend on seeps and sag ponds, are especially of concern. Cattle grazing, especially on Forest Service lands, can further exacerbate impacts to riparian areas. If climate change results in more agricultural pests, water quality could suffer due to an increase in pesticide use, negatively affecting all riparian and aquatic species.

As climate change progresses, county planners may consider new dams or dam expansions, putting riparian areas at risk. Because San Luis Obispo is unlikely to receive water delivery priority from the state, the county will need to plan for sustainable water resources over the long term.

Recommended Strategies:

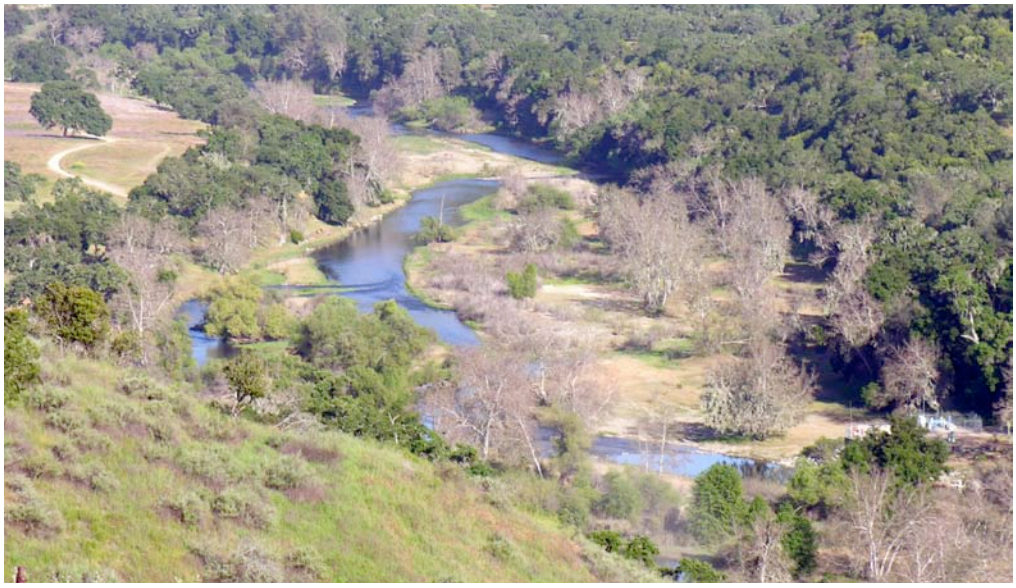
Reduce ground water use by communities and agriculture. Reducing ground water pumping could offset the impacts of reduced flow due to climate change, thereby preserving riparian and aquatic system function. Some recommended strategies for reducing water use include:

- monitor recharge and use to identify sustainable levels
- increase water prices to reflect true costs and reduce waste
- require gray water systems for many types of developments
- require low water landscaping
- require low impact development
- provide water rights for riparian and aquatic systems
- retire marginal agricultural lands and restore to conservation lands
- change to low-water crops
- buy out large water users to preserve their lands for conservation purposes

Research groundwater availability and sustainable use. This research is needed in order to develop a master plan for water resources at regional scales. Urban communities may be able to get more water from Nacimiento Lake to reduce groundwater withdrawals. Dam expansions should plan for climate change impacts to future resources, thereby retaining extra water for times of severe drought.

Reduce the influx of sediments into streams and rivers. This was also recommended in the section on coastal ecosystems, but some additional approaches to reducing sediment influx include:

- Retrofit culverts and other water facilities to prevent erosion
- Require a permit and mitigation efforts for grading near streams and rivers
- Protect, restore, and enhance floodplains, thereby increasing the ability of aquatic systems to hold high flows, filter sediment, and allow replenishment of groundwater stores
- Enforce the Clean Water Act to improve water management practices



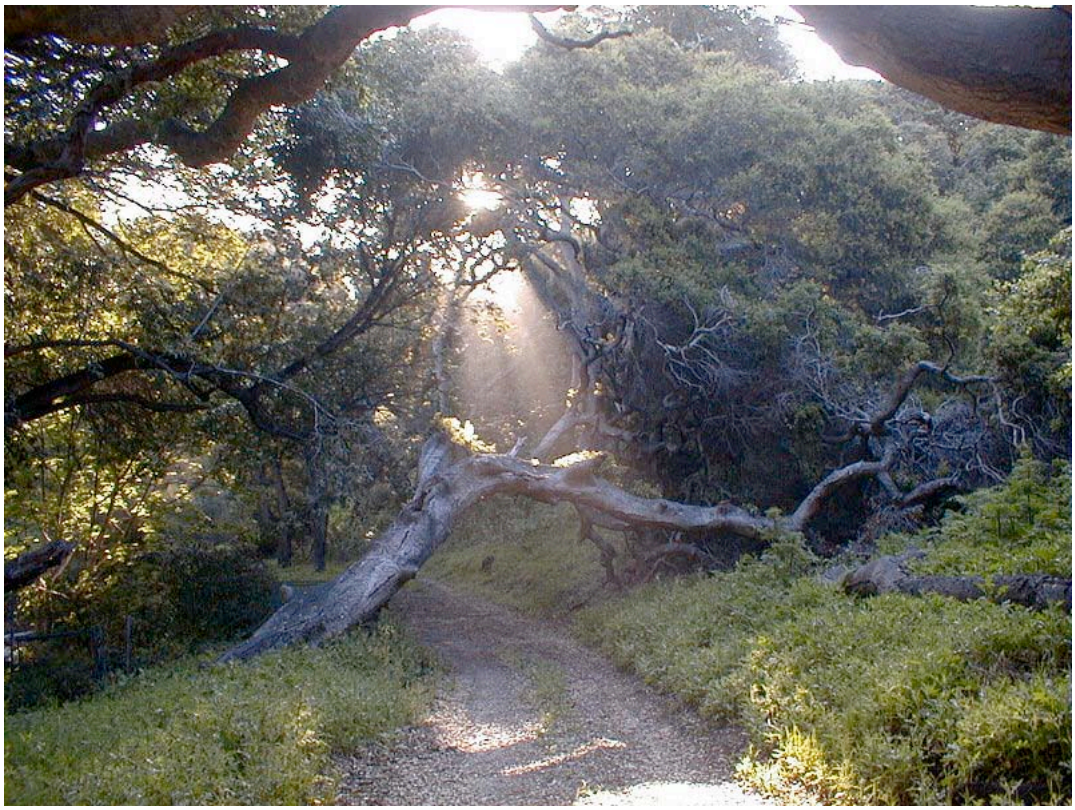
Nacimiento River; photo courtesy of Wikimedia Commons

Woodlands and Forests

Potential Impacts:

Oak woodland may decline substantially with increased disease, drought, and fire. Blue oaks are already stressed by drought in the northern part of the County and towards the San Joaquin Valley (also Santa Lucia and Caliente Plain), and are especially susceptible to fire. Non-native grasses increase the spread of wildfire. Valley oak is especially susceptible to drought. Declines in oak habitat would impact a great variety of species, including mule deer, mountain lion, bobcat, black bears, owls, woodpeckers, and numerous other species.

The future climate may not be suitable for coniferous (pine) forests and woodlands. Model projections from the vegetation model under the "business-as-usual" emissions scenario indicated that many areas of mixed pine vegetation could be unsuitable for pine by mid-century. Pine stands at higher elevations, such as those in the Caliente Mountains and Santa Lucia area, are isolated, susceptible to disease and pests, and easily wiped out by fire. Intense fire and a changing climate could prevent regeneration. The Santa Lucia range provides a migration corridor, has high fire danger, and is host to isolated plant communities that could be lost. Bishop pine and Monterey pine near Avila are also at risk, as well as Knobcone pine, which doesn't regenerate after fire. Pine in San Simeon are especially isolated. Many pines already suffer from declines in recruitment and genetic mixing.



Recommended Strategies:

Target oak woodlands on private ranches for improved management. Ranch owners are natural allies in climate change adaptation, as ranches support native species and habitats, but many ranches could be managed for functioning oak woodlands for the dual purposes of providing valuable habitat and storing carbon in vegetation. In order to maintain healthy oak woodlands and migration corridors, the following were recommended:

- incentives (tax breaks, easements, etc.) in strategic locations and habitats
- regulation that restricts land use in oak woodlands
- development of new Best Management Practices (BMPs)
- education for land owners on climate change, incentive programs, and BMPs

Reform grazing practices to increase oak recruitment, riparian vegetation, and water quality. State and federal land agencies, such as CA State Parks, USDA Forest Service, and Bureau of Land Management, may need to revisit their grazing policies, potentially removing cattle from important areas that provide water filtration, bank stability, woodland or grassland habitat and/or connectivity.

Conduct a county-wide assessment to identify areas expected to function as refuges for many species under climate change. These would include currently important habitat areas, key areas that could be restored, climate refugia (areas expected to remain stable), and areas that provide connectivity. Conservation easements should be encouraged in the areas that are identified through this effort. Funding sources for this effort will need to be identified or developed. Enforcement and definition of easements may need to be discussed at the state level.

Areas that are expected to support pine through this century should be identified and prioritized for management action. Diseased pine should be removed and burned, increasing the health of surrounding trees. If stands are too thick, thinning may be needed.

Conduct or partner in research that leads to better understanding of management options. Some suggested topics include research of more drought resistant varieties of oaks and the efficacy and ecological impacts of different management approaches in pine stands, including thinning and post fire treatments.

California quail
Photo courtesy of Wikimedia Commons

Grasslands and Shrublands

Potential Impacts:

Saltbush (*Atriplex*) and other native shrubs are expected to decline with climate change. Model projections show loss of appropriate conditions for temperate shrubland by mid-century. Shrubs could be impacted by increased drought and spread of fire with non-native grasses. Many species would be affected, including San Joaquin kit fox, LeConte's thrasher, giant kangaroo rats, blunt-nosed leopard lizards, and California condor.

Pronghorn and Tule elk might decline with decreased productivity of grasslands. Populations of these species are isolated and the topography of the Carrizo Plain and surrounding areas makes it difficult for them to move to new areas.

Marginal farmland may become even less productive and be retired in the Carrizo Plain area. This could have negative impacts on sandhill cranes, which rely on agricultural fields for food in this area. Tule elk, pronghorn, kit fox, and other arid land species could benefit if native habitat is restored. Retired farmland presents an opportunity for habitat restoration and connectivity. Encroachment of solar power installations into the area may preclude habitat restoration in key areas if regional conservation planning is not able to move forward quickly. If fallow fields are not restored to native vegetation, invasive species are likely to become more common in the area.

The Carrizo Plain, one of the largest remaining intact native California grasslands
Photo courtesy of Wikimedia Commons

Recommended Strategies:

Closely manage salt bush habitats to reduce fire risk. Invasive species such as annual grasses can act as fuel that spreads fire in this community. Controlling non-native grasses to prevent fire, reducing fire ignition sources, and quickly responding to fires in this system would be beneficial to many species that rely on salt bush habitat.

Map and conserve corridors that allow connectivity to other areas, including the Central Valley. Species currently found in the Carrizo Plain are likely to shift their ranges to new areas as the climate changes. Connections to the south, including the Tehachapi range, should be conserved so species further south can colonize the area. Maintaining a functioning native grassland and shrubland system in the Carrizo Plain should be a priority over maintaining individual species.

Increase monitoring of populations and habitat conditions. Monitoring to detect changes in populations and maintain certain components of the ecosystem will be especially vital. Many strongholds for important species, such as Tule elk, are found on private land (such as those from the Carrizo Plain to Chelome Valley to Monterey County). Private land owners could be provided with incentives (from the County or State) for protecting high quality habitat. The conservation reserve program could be expanded to provide farmers with incentives for protecting productive populations as well as turning marginal farmland into viable native species habitat or corridors for migration to new areas. Such incentives would prevent abandoned farmland from becoming dominated by invasive species.

Restore many drainages to Soda Lake that have been developed for agriculture, when land becomes fallow. These areas should be avoided for other types of development, such as solar energy development, due to their very high conservation potential and importance as movement corridors.

Limit new development to previously disturbed sites that are not important for wildlife movement. The state or county should give incentives to solar developers to make rooftop solar more competitive with large installations in natural areas due to the potential competition of solar plants with important wildlife habitat.

Giant kangaroo rat
Photo courtesy of Brian Cypher

BARRIERS TO ACTION

Current local, state, and federal policies and regulations were developed with a stable climate as an underlying assumption. As we are increasingly challenged with changing conditions, more flexible approaches that incorporate adaptive management will better serve the people and resources of the county. One example is the lack of monitoring or regulation of groundwater withdrawal throughout the state of California. Without monitoring, there is little information on how much water is being withdrawn or how much is sustainable. There is also little information on where most of the water is used, to help direct conservation efforts. Without regulation, water users have little incentive to conserve water and agricultural products correspondingly have artificially low prices on the market. Regulation, however, is controversial and burdensome – other means to reduce water use may need to be implemented to conserve water in the agricultural sector.

Drip irrigation; photo courtesy of Wikimedia Commons

Some workshop participants noted a lack of policy directing agencies to use projections of future conditions as they develop resource management plans. Incorporating climate projections into management for natural resources and for social systems (i.e. emergency services and preparedness, public health, among others) not only requires building capacity to interpret and use climate projections, but also may require policy change to allow use of climate related data in decision making and management. As an example, a recent wetland restoration project considered only historical data when identifying a suitable site. With sea level rise, this area could be under water in the next 100 years. By incorporating sea level rise projections as well as other climate change impacts into the design of restoration projects, water treatment facilities, roads, or other projects, such projects will be more effective over many decades.

The strategies developed by San Luis Obispo stakeholders and elected officials identified a number of policy improvements to address existing barriers to adapting to climate change. These policies should be considered when cities, community service districts, the County, the Council of Governments, the air district and water agencies are updating their planning documents including but not limited to: general plan elements, specific plans, form-based zoning codes, climate action plan, water master plans, hazard plans, regional transportation plans, State Implementation Plans and sustainable community strategy under SB 375.

OPPORTUNITIES

The spur of activity caused by a changing climate provides many opportunities for addressing current problems and vulnerabilities, and thus improve the local economy, social justice, and overall quality of life for all residents. Participants of the series of workshops identified numerous opportunities to improve both management approach and on-the-ground conditions.

Where to put renewable energy:

- already disturbed sites
- land with oil and gas wells
- fallow farmland dominated by invasive weeds
- previously developed parcels

Where not to put renewable energy:

- potential wildlife corridors and connectors
- potential conservation lands
- at-risk coastal areas
- floodplains or riparian areas
- areas with abundant or sensitive native species
- intact native species habitats

Incentives should direct solar installations to:

Rooftops, parking lots, urban areas, and areas that would benefit from panels for shade (schools, parking lots, etc), thereby reducing the need for air conditioning.

Climate change mitigation – As California communities react to AB32 and SB 375 and work to reduce greenhouse gas emissions, renewable energy installations have expanded and will continue to expand in the future. Renewable energy is important for mitigating climate change and reducing its long-term severity, thereby preventing some of the most severe impacts to people and natural resources. Yet renewable energy installations can have negative impacts on climate change adaptation efforts if sound decisions that prioritize low impact solutions are not made.

Ecological function – As climate change progresses, concerted efforts to restore the functionality of many systems could lead to lowered risk of flooding, drought, and wildfire. When local communities understand the value of functional ecosystems in providing services (such as flood abatement, timber production, etc.), support for the protection of natural areas, species, and processes are expected to increase.

Traditionally, floodplain restoration has fallen to fish and wildlife agencies and conservation organizations. A collaborative of cities and communities may want to also contribute to floodplain restoration efforts in strategic locations to lower the risk of floods to local residents. Additional benefits would include improved water quality, increased groundwater infiltration, and increased riparian habitat. Many recent flood events in other parts of the country (Nashville TN, eastern IA) highlight the importance of planning to lower the risk to local populations from flooding associated with climate change.

Quality of life – Preparing for climate change impacts (one critical first step in the ongoing process of adaptation) involves changes to how we plan, site, and maintain infrastructure, which roads we travel, what we produce in agriculture, how we preserve open space, and how we approach coastal management. These changes need to be made in light of climate change and other concurrent changes and stressors (e.g., population growth). As these changes are implemented, we have an incredible opportunity to improve the basic quality of life for some of the more vulnerable populations, as well as all San Luis Obispo County residents. For example, lower income residents may have limited access to air conditioning due to limited funds. Given the higher emissions of greenhouse gases if air conditioning were to increase, a better option for this population in particular (but really beneficial for all residents) would be a concerted effort to plant trees for shade, to provide open space to reduce urban heat build-up, and to provide access to public transportation that can bring people to cooler buildings on extreme heat days. In addition to providing climate change adaptation, such changes would also improve quality of life on a daily basis. It will be important to look for co-benefits such as these as new programs are implemented.

Photo courtesy of Jim Zimmerlin

Table 3. A review of select recommended strategies and their co-benefits across different sectors and with mitigation efforts.

Recommended strategy	Effect on Natural Systems	Effect on Health and Emergency Preparedness	Effect on Agriculture	Effect on Water Resources and Infrastructure	Effect on Infrastructure and Energy	Effect on Mitigation Efforts
Mandate "Smart growth" policies	Reduces sprawl into natural areas	Consolidates emergency response needs into a smaller area	Provides a market for fresh produce and other products	Reduces per capita water and energy use	Low impact design	Reduces per capita greenhouse gas emissions
Reduce groundwater use by communities and agriculture	Allow aquatic and riparian species to retain populations in the face of climate change	Water quality would increase, potentially preventing health impacts from pollutants	Could increase cost of water for agriculture, but also make it more resilient to drought	Water resources would be more sustainable		Prevent the need for energy intensive desalination
Identify and conserve climate "refuges" on private lands	Increased resilience of native species and ecosystems	Reduces sprawl into rural areas, which reduces emergency response needs	Ranch and farm owners could benefit from incentives	Higher water quality when uplands are managed sustainably		Climate "refuges" may also store carbon in vegetation
Increase local food production and independence	Reduced risk of climate change due to lower emissions	More fresh food with potentially lower risk of contamination	Increased stability and economic support	Would need new water conservation measures	Less energy (gasoline) demand	Reduce greenhouse gas emissions from food distribution
Restore and expand wetlands and floodplains	Increase resilience of aquatic and riparian species	Reduces the likelihood of flood emergencies	Could receive incentives for wetlands on agricultural lands	Increased water quality and groundwater infiltration	Reduces flood impacts to infrastructure	

CONCLUSIONS

Climate change presents new challenges for San Luis Obispo County and other jurisdictions around the globe. Yet these challenges are surmountable with timely and adequate planning and preparation. The County and the cities within San Luis Obispo are already working to update general plan elements, inventory greenhouse gas emissions and create Climate Action Plans that addresses mitigation (reducing greenhouse gas emissions). Adaptation (reducing the impacts from climate variability and change) is also needed because it is now apparent that climate change impacts are already underway and can no longer be avoided. The County's commendable efforts to reduce emissions by addressing issues across sectors, such as infrastructure, agriculture, and energy are a large step forward on the issue. By integrating climate change adaptation with ongoing mitigation efforts, the County and cities will be able to work more efficiently and effectively on both issues at once. This effort provides some initial strategies and information, as well as new working relationships, that are needed to move forward on this important issue.

Most strategies to adapt to climate change are familiar ones that have numerous co-benefits across the different sectors. By working across the sectors in an integrated manner to address climate change impacts, the County will save money, will increase communication and collaboration among disparate groups, will reduce conflict, and will save lives and prevent suffering.

One important message came across in the workshops that were held in San Luis Obispo County – this spectacular area has many advantages and opportunities as climate change progresses. For example, the coastline is relatively undeveloped compared to other California coastal areas, resulting in less potential infrastructure loss from sea level rise and coastal storms. The county is expected to support a hotspot of biological diversity under climate change. Biological diversity could help to maintain ecosystem services, and the natural landscapes that residents value. And San Luis Obispo's leadership is engaged in the issue of climate change and moving forward quickly to retain the character and quality of life of the region.

While difficult choices will need to be made, the County is in the advantageous position of beginning its adaptation efforts early. Adaptation efforts carefully vetted against other policy goals, including greenhouse gas mitigation efforts, pose an important opportunity to move toward greater long-term environmental, social, and economic sustainability.

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