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Integrated Strategies for a Vibrant and Sustainable Fresno County

March 2011

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Integrated Strategies for a Vibrant and Sustainable Fresno County

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Support for this project was provided by:
The Kresge Foundation
USDA Forest Service Mapped Atmosphere-Plant-Soil Systems Team
ESRI Conservation Grant Program

This report can be downloaded using the following link:
www.geosinstitute.org/images/stories/pdfs/Publications/ClimateWise/FresnoClimateWiseFinal.pdf

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EXECUTIVE SUMMARY

Fresno County's vibrant agricultural economy, scenic slopes of the southern Sierra Nevada range, and dramatic rivers beginning at the highest elevations and extending across the valley floor make the Fresno region a special place. Many future changes are expected, however, and many challenges already affect the quality of life in Fresno County and the surrounding region.

Climate change is a global phenomenon that has the potential for severe local impacts to natural systems in Fresno County. These impacts in turn will affect agriculture, human health, infrastructure, forestry, emergency response, tourism, and many other facets of society. Climate change impacts are expected to exacerbate existing problems while also imposing new ones. By identifying and addressing underlying vulnerabilities early, decision makers in Fresno County can increase the resilience of both the community and the resources it depends on not only to climate change, but also to other changes such as population growth and water scarcity.

This report provides a suite of strategies that was developed by local leaders and experts during a series of workshops in 2009-2010. Workshop participants developed strategies for "climate change adaptation" – the process of preparing for climate change to reduce overall impacts to natural and human communities. We view these strategies as a critical first step in what will need to be an ongoing process as the climate, the scientific understanding of the earth's processes, and other stressors such as population growth, 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, as well as peer-reviewed scientific publications, local experts and leaders identified the following as changes that are likely to occur in Fresno County by the end of this century:

- Hotter, drier, and longer summers
- More severe storms
- 80% decline in snowpack
- Increase in wildfire
- Increase in erosion and sediment
- Declines in water quality and flow in streams and rivers
- 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
- Further declines in air quality
- Increase in stress that impacts mental health
- Increase in natural disasters (floods, droughts, fires)
- Stress to water and flood infrastructure
- Reduced number of "chill hours"
- Changes to agricultural production

Workshop participants considered both climate change impacts and on-the-ground vulnerabilities as they developed a suite of recommendations for increasing local resilience across sectors and communities. These were:

Socioeconomic Systems

Health and Emergency Preparedness

- Promote "smart growth" programs and policies
- Provide education on the positive impacts of smart growth on air quality and health
- Provide energy and conservation financing
- Establish cooling centers
- Restore and protect flood zones to prevent flood emergencies
- Control disease vectors
- Increase water conservation
- Increase food safety and security

Agriculture

- Promote irrigation efficiency and technology
- Promote soil management practices that lead to water and soil conservation
- Provide education to the agricultural industry on climate change impacts, crop diseases, sustainability, best practices, and new technology
- Increase crop diversity
- Increase renewable energy production on farms
- Increase information sharing on food-borne illness
- Restore natural systems to provide shade and cooling for livestock
- Provide incentives for restoration of wetlands, riparian areas, and meadows on farms to increase water quality
- Build capacity for increased readiness and adaptability
- Increase support for local food production and distribution

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Water Resources and Infrastructure

- Improve natural flood protection and water filtration by restoring/creating floodplains and wetlands
- Restore natural areas that provide groundwater recharge during high intensity storms
- Construct new basins for groundwater recharge
- Increase water conservation through landscaping, water storage, and pricing
- Flood control efforts should partner with conservation efforts focused on protecting and restoring key ecosystems and wildlife corridors
- Improve wastewater treatment
- Improve management of groundwater through local programs that encourage or require sustainable use
- Due to the uncertainty associated with precipitation projections, high cost, and impacts to natural systems, construction of new reservoirs was not recommended at this time

Infrastructure

- Increase maintenance and improvement of infrastructure to withstand severe weather events
- Conserve water through efficiency measures
- Install water meters so water rates reflect the true cost
- Coordinate land use decisions with public transit design
- Preserve open space through conservation easements and the Williamson Act
- Retrofit existing buildings to meet green standards

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.

Rosemarie Amaral, Susan Antenen, Ken Austin, Craig Bailey, Keith Bergthold, Julia Biggar, Tony Boren, Beverly Bulaon, Kristine Cai, Laura Colton, Carole Combs, Brian Cypher, Stacie Dabbs, Lauren Dawson, Kathy Dervin, Michelle Dooley, Mike Dozier, Rebecca El-Bendary, Cynthia Echavarria, Julie Ekstrom, Lorraine Flint, Marion Gee, Bruce Goines, Lynn Gorman, Kathleen Grassi, Rich Green, Matt Griffis, Ken Grimes, Rob Hansen, Frederika Harmsen, Steve Haugen, Steve Haze, Glenda Hill, Chrissy Howell, Don Hunsaker, Genoveva Islas-Hooker, Elizabeth Jonasson, Dorothea Jones, Alan Journet, Bobby Kamansky, Holly King, Steve Laymon, Chris Lehn, Clifton Lollar, Bill Loudermilk, Ryan Lucas, Martin MacKenzie, Tom Matott, Christina McDonald, Joe Mediola, Jeanne Merrill, Marc Meyer, Richard Molinar, Ed Moreno, Susanne Moser, Ron Nishinaka, Vahid Nowshiravan, Joseph Oldham, David Orth, Eric Osterling, Donald F. Pauley, Laura Pennebaker, Paul Pierce, Cruz Ramos, Bob Riding, Arnoldo Rodriguez, Rocky Rogers, Belinda Rosette, Lucinda Roth, Nick Santos, Sahara Saude, Terry Schmal, Michelle Selmon, Samir Sheikh, John Shelton, Franklin Spees, Janet Stanovich, Barbara Steck, Jeanette Sutherlin, Tina Terrell, Clark Thompson, Kevin Tucker, Jeannette Tuitele, Darrell Unruh, Peter Van de Water, Liz van Wagtendonk, Winona Victery, Alan Weaver, Tom Webster, Tory Westall, John Wright*

* We apologize for our oversight if you participated in the process and your name is missing or misspelled.

Species and Ecosystems

Freshwater Aquatic and Riparian

- Reduce water use by communities and agriculture through metering and recycling
- Establish and restore natural retention ponds and storage that benefit wildlife and agriculture
- Restore natural function to floodplains and stream channels
- Restore and greatly expand riparian areas along all waterways
- Restore montane meadows and wetlands to store more water at higher elevations
- Preserve cold water aquatic systems through strategic management of water release and storage

Woodlands and Forests

- Manage forests for heterogeneity , employing different management approaches depending on local conditions and scientific support
- Use controlled burns or ecologically sound thinning to reduce the chance of high severity wildfire
- Implement rapid detection and response to invasive species
- Identify and protect future climate refuges and linkages

Valley Floor Grasslands and Semi-desert

- Map and conserve corridors that allow species to move northward along the valley floor and into the foothills
- Develop Best Management Practices (BMPs) for federal lands, with incentives for private landowners to follow BMPs.
- Improve agricultural practices to support fish and wildlife habitat
- Restore fallow farmland to native habitat

PURPOSE AND OVERVIEW

Fresno County is faced with many challenges over the coming decades. The population is expected to continue to grow, current air pollution and water shortage problems could worsen without action, and pressures on natural areas from development are expected to continue. In addition to these pressures, climate change is expected to cause even more severe impacts across all sectors of society.

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 stressors and changes in Fresno County. Actions taken now can reduce stressors and improve the quality of life that residents of this exceptional and diverse region have come to enjoy. By preparing for change in a cohesive and ecologically sound manner, Fresno County will not only reduce the vulnerability of community members to stressors such as poor air quality and drought, but willalso maintain the value of services, such as tourism, flood abatement, water supply, 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 Fresno County, including elected leaders, county planners, land managers, public health officials, concerned citizens, and others who joined us in three workshops that form the basis for this report. These individuals came together to discuss the threat of climate change to the community and the likely interaction

…this report is a reflection of input, values, and opinion from local experts, leaders, and citizens.

between climate change and other stressors. They were tasked with developing a suite of 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 is a reflection of input, values, and opinion from local experts, leaders, and citizens.

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.

Fresno County was chosen as a pilot location based on a number of factors, including agricultural importance, federal land ownership, diverse habitats, vulnerable species conflicts, rural and urban populations, severe current threats, cultural diversity, and other factors.

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.[1] Severe storm and wildfire frequency have increased throughout the western U.S.[2] Globally, species of animals and plants are already on the move as a result of the warming climate.[3] 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 Fresno County's vulnerability to the impacts of a changing climate, but by themselves these adaptive strategies will be insufficient over long time scales (50+ years) if emissions are not also cut.

Climate change "adaptation" refers to actions that communities, governments, and individuals take to reduce their vulnerability to climate change impacts.

GLOBAL CHANGE

Measurements from around the globe indicate that the Earth's atmosphere and oceans are warming.[4,5] 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). This warming is due primarily to human activities including deforestation and the emission of CO_2, methane, and other greenhouse gases.[4,5]

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[6] 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.[5] Wildfires could increase worldwide, due to vegetation stressed by higher temperatures, disease, and insects. Air quality will decline from wildfires and as higher temperatures lead to increased ozone formation.

Approximately 30% of all species are at risk of extinction from climate change.[7] 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.

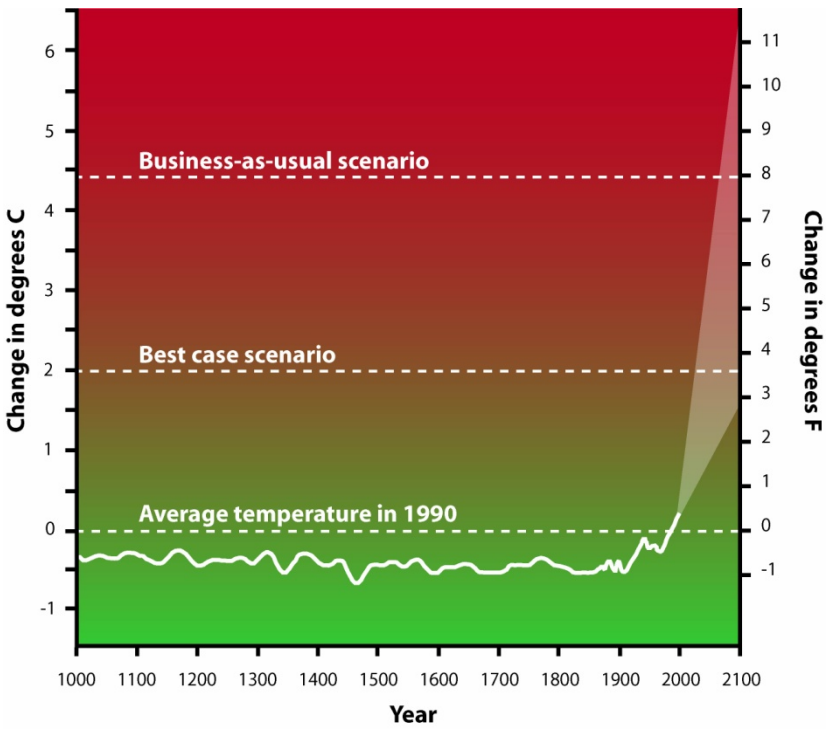


Figure 1. The last 1000 years in global mean temperature, in comparison to projected temperature for 2100. Drastic cuts in greenhouse gas emissions may lead to an increase of about 3° F by 2100 while the current emissions trajectory could lead to an increase closer to 8° F and as high as 11° F (adapted from IPCC 2007[4]).

Other species will lose important food resources or their breeding or migration timing will be disrupted by climate change. As ecosystems unravel, many natural benefits, such as flood control, water filtration, pollination, and timber production, could be compromised or lost.

While the impacts of current stressors and additional stressors brought on by climate change are expected to be severe, local communities can begin to take action now to reduce their vulnerability. This is called climate change "adaptation." Many approaches to climate change adaptation also reduce the impacts of other threats, like poor air quality, drought, or habitat loss. This report provides a suite of initial strategies that can be implemented to reduce vulnerabilities in a co-beneficial way across multiple sectors. 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.

Why make changes if the future is uncertain?

While the models agree that average temperature will increase, projections for other factors such as precipitation or greenhouse gas emissions are high variable. Why would we invest time and resources into planning for such 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. Yet no climate models predict continued historic conditions. Relying on continued historical conditions for a community's needs, such as water for residents, winter chill for crops, or snow for recreation, will likely lead to failure.

#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. The severe potential cost of climate change (by some estimates, around 13% of national GDP by 2040) is so high that we would be prudent to plan proactively and reduce that risk.

#3 – Taking action makes the community more resilient and vibrant, regardless of the actual trajectory of climate change. Fresno County is already at risk from extended drought, poor air quality, competition for water, and loss of agricultural and natural lands to development. By addressing these and other issues now, County residents' quality of life 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.[4] This scenario closely followed the global emissions path of the late 1990s; a sharp rise in emissions since 2000 means that emissions during the past decade exceeded those used in the modeling in this report[8] (see also http://www.realclimate.org/index.php/archives/2010/06/recent-trends-in-co2-emissions/). Consequently, the climate projections indicated in this report may underestimate future trends. A concerted effort to lower emissions could, in contrast, lead to lower temperatures than those depicted in this report. Because of time lags 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 more uncertain.

Climate Models

Please see the companion report, "Future Climate Conditions in Fresno County and Surrounding Counties", for more information on the models, modeling assumptions, uncertainty, and projections (www.geosinstitute.org/images/stories/pdfs/Publications/ClimateWise/FresnoModelReportFINAL.pdf).

Scientists at the Geos Institute explored potential future climate conditions in Fresno County using three global climate models – CSIRO, MIROC, and HadCM (for a thorough discussion of the models, see Randall et al. 2007[9]) 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 reflect new information.

CLIMATE CHANGE IN FRESNO 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 Fresno County can increase the resilience of the community and the resources on which it depends.

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.[10] 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. A companion report[13] provides more in-depth coverage of model assumptions, emissions scenarios, uncertainty, and projections for Fresno 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 occur sooner than projected. Additionally, as models are refined and updated, projections for future conditions could change considerably.

Climate change is expected to result in changes to the region, including:

- 2-6° F increase in temperature by mid-century and 4-11° F increase by late century
- Long term declines in precipitation by 6-32%
- 80% decline in snowpack
- Earlier snowmelt with higher and earlier peak runoff
- Declines in groundwater recharge, stream flow, and water availability
- 2-4 times more wildfire at upper elevations
- Declines in populations of native animals and plants and shifts in distributions
- Increases in invasive species
- Further declines in air quality

…all models predict, to varying degrees, warmer temperatures and lower snowpack

Precisely predicting future conditions is not necessary for implementing sound strategies that reduce local vulnerabilities. For instance, all models predict, to varying degrees, warmer temperatures and lower snowpack, regardless of precipitation trends. Droughts are expected to be more frequent and severe. Thus,

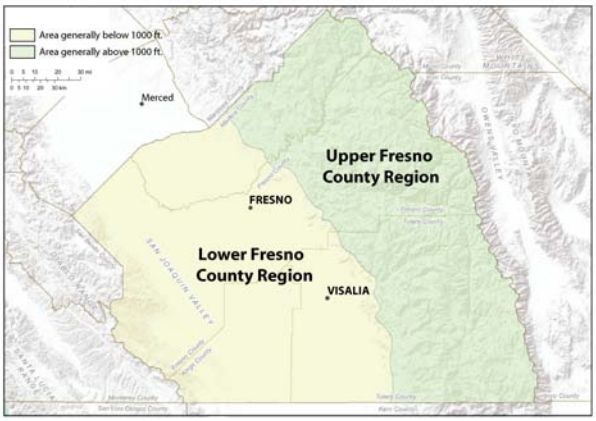


Figure 2. Areas referred to in this report as "Upper" and "Lower" Fresno County region. The Upper Fresno County Region is generally above 1,000 feet in elevation and is found in the eastern portions of Fresno, Madera, and Tulare counties, while the Lower Fresno County Region is generally below 1,000 feet in elevation and encompasses western portions of Fresno, Madera, and Tulare counties as well as all of Kings County.

planning for increased resilience in the face of drought is considered a "no-regrets" strategy – such a strategy would benefit the County regardless of climate change and it addresses a relatively certain risk.

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 both money and lives. While climate change is the impetus for this effort, adopting the strategies recommended in this report would benefit residents of Fresno 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, the Fresno County region is expected to become 3-5° F warmer by mid-century and, depending on emissions, 5-9° 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 the upper and lower Fresno County regions (see Fig. 2 for details), from three different global climate models. Future projected temperature is shown as change in degrees Fahrenheit, as compared to historic averages (1961-1990).

	Historic		2035-45		2075-85	
Season	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**
Annual	46.4° F	62.3° F	+2.5 to 4.8° F	+2.3 to 4.3° F	+5.2 to 8.9° F	+4.7 to 8.2° F
Summer	61.3° F	78.0° F	+2.2 to 6.0° F	+2.0 to 5.4° F	+5.8 to 11.0° F	+5.2 to 10.0° F
Winter	33.9° F	47.0° F	+2.2 to 4.1° F	+2.0 to 3.8° F	+4.1 to 7.9° F	+3.7 to 7.4° F

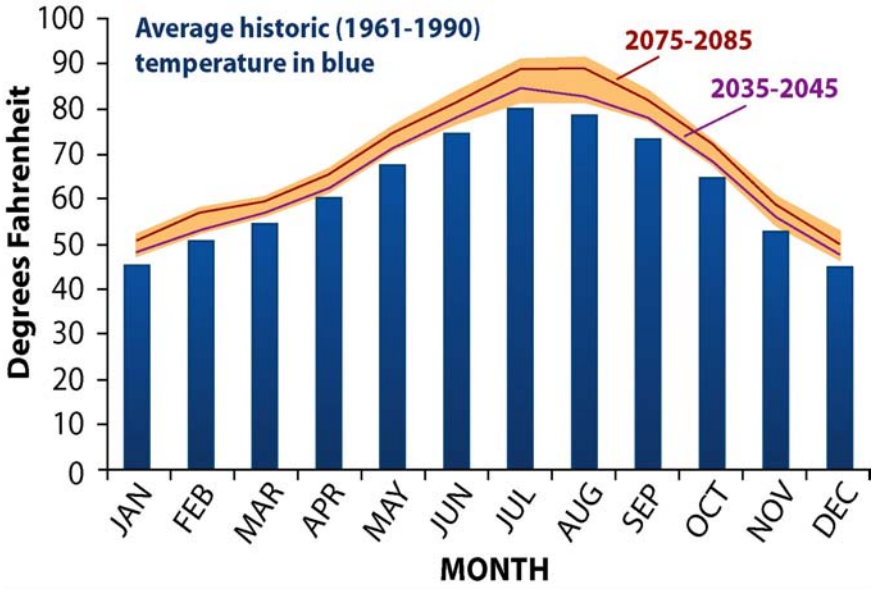


Figure 2. Average monthly temperature across the Lower Fresno County region. Future projections are averaged across the three global climate models for two different time periods: 2035-45 (purple line) and 2075-85 (red line). The full range of projections from all three models is shown in orange

Precipitation – Model projections for precipitation were highly variable. Mid-century projections ranged from a decline of 28% to an increases of 13%. Most projected change occurs in January-May (Figure 3). By late century (2075-85), all three models agree on drier conditions for both the upper and lower Fresno County region (precipitation down by 6% to 32%).

Precipitation is expected to fall increasingly as rain instead of snow as the snowline moves upward in elevation. Overall declines in precipitation and the shift from snow to rain are expected to act in concert to cause severe reductions in snowpack (up to 90% lost by late century; Cayan et al. 2009).

Vegetation change – A vegetation model (MC1) from the USDA Forest Service's Pacific Northwest Research Station projects future growing conditions and wildfire patterns for Fresno 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 changed growing conditions in areas that are currently dominated by sequoia and mixed conifer (currently sugar pine, white fir, incense cedar, etc.). Lower elevation conifers, such as gray pine, may spread to higher elevations. Despite changed growing conditions, vegetation can take decades or centuries to adjust, especially at higher elevations where conditions will become more hospitable to forest but suitable soils could take centuries to develop.

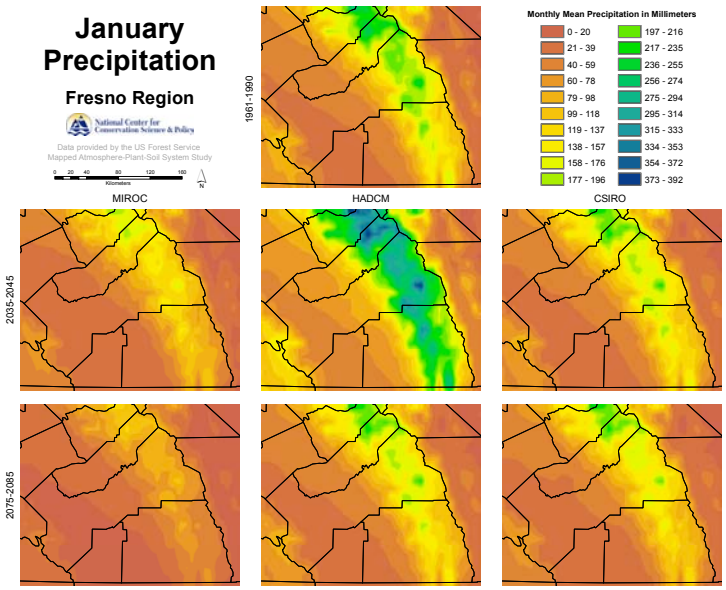


Figure 3. Average January precipitation, in millimeters, across Fresno County – historically (top) and projected for 2035-45 (middle row) and 2075-85 (bottom row). Projections are based on three different global climate models (MIROC, HadCM, and CSIRO).

Wildfire – Westerling[2] projected substantial increases in total average area burned by wildfire, with the eastern portions of Fresno County expected to experience 200-400% greater acreage burned by 2085 as compared to the historic (1961-1990) amount. Similarly, the MC1 model projects 2-4 times greater biomass consumed by wildfire at upper elevations 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.

Air quality – Climate and air quality are closely coupled. Conventional pollutants such as ozone and particle pollution affect public health and also exacerbate climate change. Higher temperatures cause increased ozone formation, with increases up to 11 parts per billion expected in Southern California by 2050.[11] Changes in air stagnation are also expected to exacerbate air quality in much of the western U.S.,[12] including the Central Valley.

BOTH ADAPTATION AND MITIGATION ARE VITAL

Greenhouse gas emissions from today will tie us in to 30 to 50 years of increasingly severe impacts. Cuts in greenhouse gas levels, however, could prevent some of the most severe impacts to our children and grandchildren.

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, planting trees in residential areas will decrease the need for air conditioning (mitigation), sequester carbon (mitigation) and increase livability even as temperatures increase (adaptation).

"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.

In other cases, adaptation and mitigation can undermine each other or other policy goals. For instance, use of air conditioning during a hear wave us a sound adaptation response, but it results in greater fossil fuel combustion and undermines mitigation efforts. 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 to survive the crash intact.

COMPLEMENTARY EFFORTS

Many planning processes that increase the resilience and sustainability of Fresno County and surrounding areas are complete or in the works. Many of the actions recommended in this report are also recommended in other efforts, but often for different reasons. As we prioritize specific actions for implementation, it will be important to look for overlapping strategies that benefit multiple sectors and communities. Below we list many relevant planning documents and provide a short summary of their objectives and how they overlap with this effort and others.

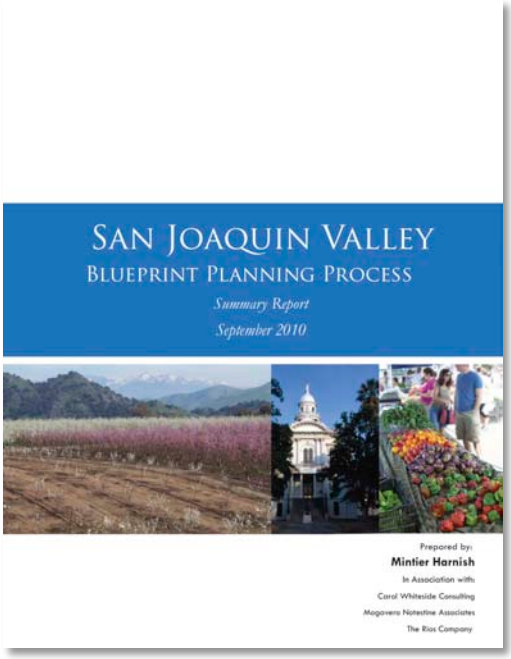
Fresno County/San Joaquin Valley Blueprints

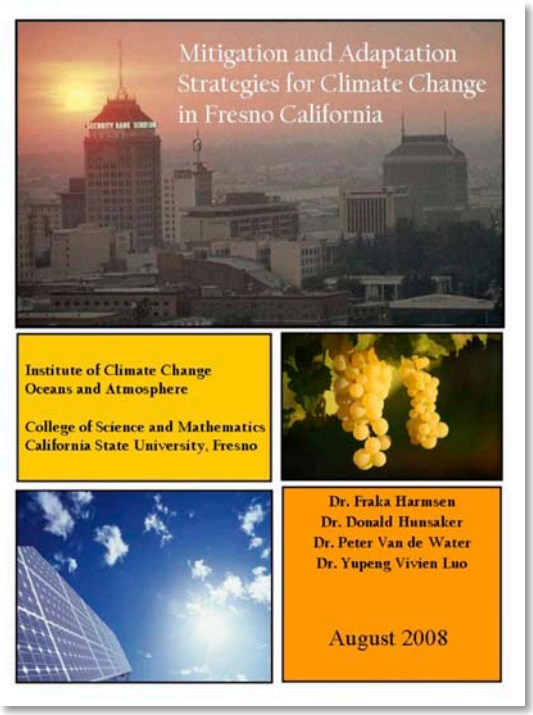
One of the most influential planning efforts in the region is the San Joaquin Valley Blueprint.[13] In early 2006 eight Councils of Governments in the San Joaquin Valley began developing a common vision for the Valley – the San Joaquin Valley Regional Blueprint. This blueprint was based on eight individual county blueprints.

Fresno County's Blueprint[14] is intended to help urban areas in the County better deal with existing and expected growth-related challenges. Population growth is likely to present challenges to public resources, housing, mobility, public health, air quality and the natural environment. While its emphasis is on economic and demographic growth and changes, the Blueprint recognizes that the natural environment is already under growing pressure from development and is likely to face additional stress from impacts related to a changing climate.

Strategies outlined in Fresno County's Blueprint are highly compatible with those developed for this report. Some examples of suggested strategies that are complementary include:

- Implement smart growth principles
- Conserve important ecosystems that lead to flood abatement, groundwater infiltration, wildlife movement, and other benefits
- Conserve important agricultural lands
- Plan for future water needs
- Encourage community and stakeholder collaboration
- Diversify the economic base





Mitigation and Adaptation Strategies for Climate Change in Fresno

In 2008, experts at the California State University in Fresno (CSUF) completed a study for the City of Fresno to assess what specific additional challenges may be arising from climate change, and how the City might address them[15]. The resulting study laid out potential climate-related threats and suggested a variety of actions local governments, in collaboration with the private sector, could take to reduce greenhouse gas emissions. It also offered a limited number of actions to deal with the unavoidable impacts of climate variability and change, such as increasing heat extremes. Virtually the entire suite of proposed strategies and actions are consistent with, and in fact integral to, the County's Blueprint principles and strategies.

Some examples include:

- Follow Fresno Green standards for energy efficiency in new buildings
- Encourage "smart growth" (e.g promote higher density, mixed use neighborhoods)
- Retrofit existing buildings for efficiency
- Improve transportation efficiency

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. The purpose of this report is to provide insights and information to augment existing efforts, to refine current strategies, and to help local decision makers meet the challenges of the future and ensure the realization of Fresno County's vision.

Tulare Basin Connectivity Planning

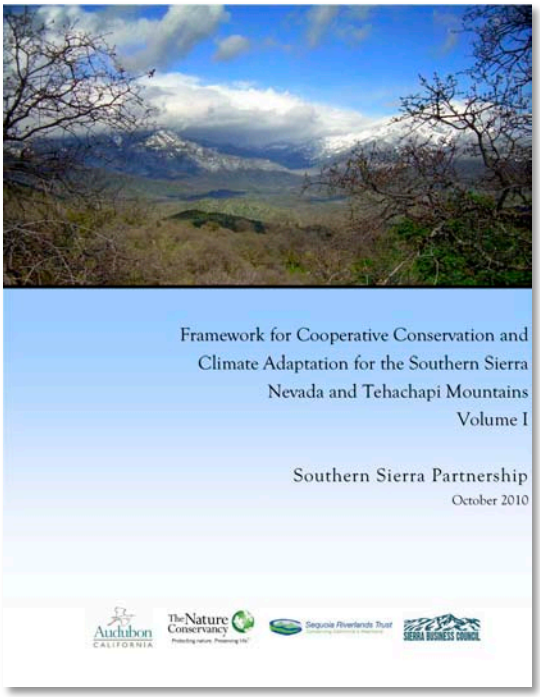
In 2009, the Tulare Basin Wildlife Partners (TBWP) completed four comprehensive conservation plans for the Tulare Basin (three regional plans and one Basin-wide plan for riparian and wildlife corridors). These plans detail goals and management objectives that will enhance, protect and restore wildlife and their habitats for each planning area. TBWP uses a wide range of conservation tools to work with willing and interested landowners and government agencies to protect or restore important farmland, ranchland and areas with natural habitat throughout the region.

Tulare Basin Water Use Planning
In 2010, the TBWP completed the Tulare Basin Conservation Plan Water Supply Strategies Report.[16] This uniquely valuable report details the water needs of existing and potential wetlands and riparian areas for the entire Basin. The report shows that there are a number of opportunities for TBWP to work with water management entities -- districts, agencies, and Integrated Water Management Planning (IRWMP) groups -- by helping them to satisfy the increasingly important environmental enhancement or mitigation requirements of successful projects and/or grant applications. Some potential partners include the Kaweah Basin IRWMP, Kern County IRWM, Poso Creek IRWM, Southern Sierra IRWMP, Tule River IRWMP, and the Upper Kings Basin IRWM Joint Powers Authority.

IRWMs play a key role in addressing many of the recommendations contained in this report. Under Proposition 84, the Upper Kings Basin IRWM will be evaluating the effects of climate change on the planning area, including water supply, flood management, and water quality. The Upper Kings Basin IRWM, as well as other IRWMs, are expected to play a lead role in addressing the impacts of climate change throughout the region.

Sierra Nevada Forest Management
The USDA Forest Service issued a General Technical Report[17] that provides guidance on ecosystem management for mixed-conifer forests of the Sierra Nevada range. The report explores the impacts of climate change and how forest management will need to promote and respond to heterogeneity across the landscape.

The National Park Service, Forest Service, and University of California are currently working on a joint project to conduct an in-depth vulnerability assessment and scenario planning exercise for the southern Sierra Nevada bioregion. The focus will be on fire management scenario planning for the Sierra Nevada forests, woodlands, and shrublands, but with broader implications resulting from climate change. This 2-year process has just begun.

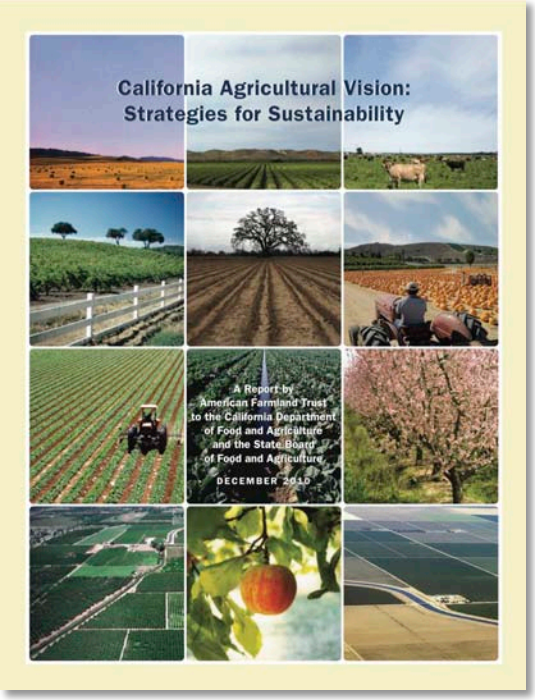


Southern Sierra Nevada and Tehachapi Range Conservation Planning
The Southern Sierra Partnership, a collective of local and regional organizations, commissioned a study of future conditions in the Southern Sierras and Tehachapi Range. The study[18] included a scientific assessment of climate change impacts

throughout the region. The group developed a framework for conserving important natural benefits, such as groundwater recharge, plants and wildlife, and development opportunities. They pinpointed areas that are expected to act as climate change refuges for important species of the region, and other areas that are slated for future development. The framework provides a map of future opportunity for the region to maintain natural resources and economic activities that support local residents' quality of life.

Some main concepts that guided the development of the conservation framework for the Southern Sierra Nevada Mountains were complementary to climate change adaptation strategies presented in this report, as well as strategies from the Fresno Blueprint, Tulare Basin Wildlife Partners' Connectivity planning, and other ongoing efforts aimed at improving the sustainability of local communities. Suggested strategies include:

- Increase and maintain connectivity of natural habitat
- Identify and conserve important natural services, such as groundwater infiltration and forage production
- Conserve foothill habitats that support high biological diversity now and into the future
- Restore valley wetlands
- Increase collaboration and communication across land ownership boundaries
- Provide incentives for private landowners to conserve important linkages and habitats
- Increase acquisition of important lands for conservation
- Improve management on public lands to increase ecosystem resilience



AgVision 2030

The California State Board of Food and Agriculture developed a strategic plan for the future of the state's agriculture and food system.[19] Its motivation was the rapidly growing list of challenges facing agriculture, from regulations and water supplies to urbanization and climate change.

Seven short-term action priorities were established: regulatory improvement, immigration reform, water security, land and natural resources, better access to healthy food, invasive species and environmental stewardship.

VULNERABILITY IN NATURAL AND SOCIOECONOMIC SYSTEMS

Future impacts throughout the county will result from the interaction of two main components: (1) challenges brought on by climate change, population growth, or other stressors, and (2) vulnerability of the local economy, communities, and natural resources to those challenges. With better understanding of specific challenges expected for this region, as well as local vulnerabilities, effective strategies to reduce overall impacts can be developed.

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 the 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.

Susanne Moser Research and Consulting completed a qualitative social vulnerability assessment for Fresno County (accessed at http://www.lgc.org/adaptation/fresno/). Using data from the U.S. Census about demographics, economics, emergency response and preparedness systems, public health, general plans and associated 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. Local stakeholders who participated in the workshops considered the components of vulnerability as they developed adaptation strategies.

Climate change will most affect those individuals and systems that have both the greatest **exposure** and **sensitivity** to climate change impacts, in addition to the lowest **adaptive capacity** (see box). 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. These groups experience greater exposure and sensitivity and

generally have a lower capacity to adapt to the impacts of climate change.[20] 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.[20] 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.

Table 2. Examples of climate-related extreme events interacting with the three components of climate change vulnerability (adapted from Moser and Ekstrom[20]).

Components of Vulnerability	Climatic Risks	Populations or Resources Particularly At Risk
Exposure	Floods	Floodplain residents
	Heat	Outdoor workers, agriculture
	Wildfire	Residents living near natural vegetation, wildlands
	Drought	Agriculture
	Lower stream flow	Fish and other cold water species
Sensitivity	Heat	Infants, elderly
	Air pollution	Asthma sufferers, children
	Drought	Water intensive crops
	Wildfire	Drought stressed forests
Adaptive Capacity	Floods	Institutionalized populations, households without flood insurance
	Infectious disease	Residents without access to medical care or prevention
	Drought	Farmers growing water intensive crops
	Heat	Low-income residents, outdoor workers
	Warmer streams and rivers	Fish without access to higher elevations due to dams

LOCAL VULNERABILITIES, IMPACTS, AND STAKEHOLDER RECOMMENDED ADAPTATION STRATEGIES

The first step towards planning for changing conditions was to identify where the county and its residents are most vulnerable to the impacts of change. A socio-economic vulnerability assessment was conducted and is summarized below. The second step was to meet with local stakeholders, leaders, and experts to determine how climate change is expected to interact with natural and socioeconomic systems to impact local residents and resources. The third step was to develop strategies to reduce vulnerabilities, impacts, or both. Finally, strategies that provide widespread benefits and are effective regardless of the exact trajectory of change, were prioritized. The results of the stakeholder driven process are presented here.

The vulnerability assessment[20] revealed the following:

- **Outdoor workers exposed to extreme heat** – Outdoor workers are directly exposed to weather, including temperature extremes and air pollution.
- **Floodplain residents at risk from extreme runoff and flooding** – People living in floodplains along the San Joaquin and Kings Rivers, downstream of the Big Creek Dam (City of Fresno) and Pine Flat Dam are particularly at risk.
- **Infants and elderly have greater sensitivity to extreme heat** – Infants and those 65 years and older are physiologically more sensitive to high temperatures and may be less able to protect themselves from extreme heat.
- **Higher sensitivity of the elderly and children to air pollution** – Poor air quality will be exacerbated by increasing temperatures that cause increased ozone formation. Children, the elderly, and those with preexisting pulmonary conditions are most sensitive.
- **Lower income correlates with lower disaster readiness and response** – Lower income often correlates with lower access to resources to prevent, prepare for or evacuate in the case of a disaster.
- **Less education can undermine adaptive capacity** – Less education can lead to lower average salaries and less access to information, insurance or health care, causing lower adaptive capacity during natural disasters.
- **Race and environmental injustice in adaptive capacity** – Language barriers and lower average salaries can lead to lower capacity for responding to or preparing for disasters among minority populations.
- **Limited mobility, fixed incomes and the adaptive capacity of the elderly** – Mobility challenges and dependence on limited fixed income can restrict the ability of the elderly to take proactive measures.
- **Renters with limited control over housing** – Renters have little control over structural adjustments for flood protection or insulation from heat, etc.
- **Students and institutionalized populations** – Students tend to be less connected to their resident community, they may not own vehicles, and have a lower response rate to public warnings. Pleasant Valley State Prison, just north of Kettleman City, has about 5,200 inmates. The prison is located adjacent to a high risk flood zone, and may be exposed to flooding during future high runoff or rainfall events.

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. Research clearly demonstrates that long-term exposure to air pollutants increases the risk of respiratory illnesses such as allergies, asthma, chronic obstructive pulmonary disease, and lung cancer. In addition, plants may produce more allergens with higher levels of CO_2 in the atmosphere. Finally, increases in cardiovascular disease have also been linked to higher levels of pollution.

Community Organizations and Social Capital: Enhancing Adaptive Capacity

Social groups can be important resources for communities in cases of emergency. They provide resources and support and can help increase public awareness about what households and communities can do to cope with and adapt to the impacts of climate change. Trustful social relations are among the most important immaterial resources during times of stress and change. Social groups can develop strategies for helping individuals and families to become familiar with the risks, take actions to reduce their exposure, assist targeted populations during emergencies (e.g., a social buddy system during heat waves), and support each other in the aftermath of disasters to rebuild and bounce back more quickly.

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. Climate change is expected to lead to an increase in the number of climate- and weather-related extreme events, such as wildfires, droughts, flooding and heat waves, thus increasing the demand for emergency services.[17] In addition, increased stress from temperature and water related events could impact mental health.

Stakeholder Recommended Strategies:

Promote smart growth programs and policies. "Smart growth" principles encourage bicycling or walking. Improvements in residents' health could increase their resilience to climate-related stressors (such as heat and disease). Smart growth policies enhance mitigation efforts by reducing greenhouse gas emissions from vehicles. Local stakeholders suggest conducting research on the positive impact smart growth can have on air quality and health and educating the public. Policies and programs should also address energy and natural area conservation.

Smart growth policies should be adopted through the Regional Blueprint, Sustainable Community Strategies, General Plans, form-based codes (which place a primary emphasis on structural features rather than primary use), building codes and the permitting process at the city and county level. Energy and conservation financing and other incentives should be identified.

Reduce exposure to climate change impacts. Local governments should increase community preparedness through education and outreach with an emphasis on protecting sensitive populations. Specific measures like urban greening should be implemented to plan for increased temperatures and other expected threats.

Local governments should provide energy and conservation financing and incentives; establish cooling centers; and undertake public education and communication, including disease prevention education and early notification.

Protect flood zones. Local governments should upgrade infrastructure and consider strategies like using dry lakebeds to hold water. It will also be important to address health concerns related to flooding such as controlling disease vectors.

Cities and counties should protect flood zones by revising building codes and storm drain systems; using water-permeable paving; reclaiming waste water; restricting growth in flood plains; conserving wild lands; and undertaking disease prevention education and communication, especially for vector-borne disease.

Conserve water. Local governments should restrict building where there is no water supply. Cities and counties should implement polices and incentives that lead to water conservation, implement polices and incentives to manage recharge basins, and promote research on water-wise agriculture.

Increase food safety and security. Natural disasters could impact food supplies, County government should ensure that local agriculture is protected and that residents are not dependent on imported food that may be at risk. The county and cities within can do this by:

- designating sites for community gardens and farmers' markets
- implementing policies for efficient land use and farm land conservation like Agriculture Preservation Zoning
- expanding WIC programs
- expanding USDA capacity for food inspection

2. Agriculture

Climate change poses a serious threat to agriculture for Fresno County. Given the dominance of the agricultural sector in terms of production value and employment, negative impacts on this industry will reverberate throughout the county and affect farmers, their employees (many of whom are among the most vulnerable social groups), related industries and, consequently, local government budgets.

Potential Impacts:

Climate change-related threats to agriculture in Fresno County include:

- Higher temperatures
- Reduced water availability
- More intense downpours
- Increased water demand
- Reduced number of chill hours (periods with low temperatures)
- Reduced populations of pollinators
- Increased risk of pest infestations and spread of invasive plants
- Decline in forage quality and quantity for cattle and sheep

The ability for farmers and farm workers to deal with climatic changes depends on a number of factors. In general, farmers with less acreage, fewer financial, technological, and water resources, fewer or less flexible response options, limited crop diversity, fewer risk sharing opportunities, or greater dependence on farm income tend to be more vulnerable to climate change. Outdoor workers in farming, especially in hotter 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.[20]

Stakeholder Recommended Strategies:

Promote irrigation efficiency and technology and soil management practices.
The county in cooperation with the Farm Bureau and the University of CA Cooperative Extension (UCCE) should work to develop and promote measures that reduce water used for irrigation and reduces impacts on soil such reducing tilling.

The county should form a network with cities, local farmers, the Council of Governments, and state and federal government to combine resources, best practices, financing, incentives and technical assistance.

Provide education to the agriculture industry. Efforts should be made to increase tracking, data, and data availability on the effects of climate change on agriculture. The emergence of crop diseases should be monitored and reported to ensure quick response. Education and outreach should be provided on the benefits of crop rotations to maintain soil quality and organic agriculture to reduce dependence on petro-based chemicals. Increased coordination among farmers is recommended to share best practices and help respond to newly emerging impacts.

Local governments should work with groups like University of CA Cooperative Extension (UCCE) and the Farm Bureau to increase field observation and monitoring, develop a climate information services/early warning system and estimates of weather and climate impact on crop production. Local governments can implement US Department of Agriculture (USDA) programs such as Environmental Quality Incentives Program and urge cooperation between USDA, California Department of Food and Agriculture (CDFA) and Department of Public Health (DPH) to share information about food borne illnesses which could increase as climatic factors influence the growth and survival and transmission of pathogens. Higher temperatures increase replication cycles of food-borne pathogens, and prolonged seasons may augment the opportunity for food handling mistakes

Increase crop diversity and resource efficiency. Education is needed on the importance of crop diversity and resource efficiency. Chemical and water efficiency for agriculture should be encouraged and incentivized. Local governments should reduce barriers to on-farm renewable energy production (including reassessing zoning and permitting), encourage farmland set-asides (farmland not used for food production), and encourage restoration of riparian zones, flood plains, and meadows with native vegetation and natural flows.

Education campaigns should be developed to encourage the public to buy food grown locally.

Develop an infrastructure that reduces vulnerability to climate change impacts. Strategies could include restoring oak woodlands and managing rangeland to provide shade and cooling for livestock, implementing feed management and educating consumers on dairy impacts, demand-side management.

Funding should be identified for these measures. Local governments should implement education and incentive programs.

Build capacity within the agriculture industry. Education, research and new financial resources should be dedicated to increase institutional readiness and response, increase crop/farm adaptability and increase local markets/production.

Local governments should change permitting to allow for community garden, farmers' markets, community supported agriculture (CSA) and provide support for local farm-to-institution programs.

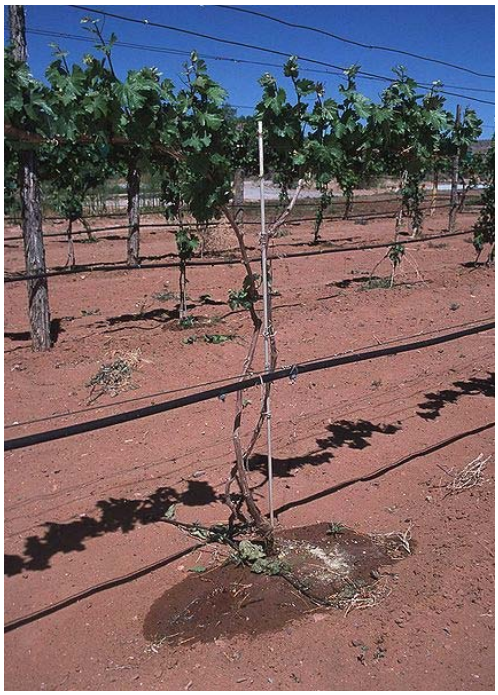
3. Water Resources and Infrastructure

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 are expected to worsen. Sufficient water supplies are crucial to the county's agricultural industry and residents. Water supply shortages are already a serious problem for many regions in Fresno County. Under the projected climate changes, the county could experience generally drier conditions, due to increased evaporation coupled with the potential for lower rainfall. Climate change is also projected to lead to a reduction in snow pack and earlier snowmelt. Water supply shortages could lead to higher prices for water and food.

Climate change could also cause reduced groundwater recharge. The region may see more severe (but not necessarily more frequent) rainfall events, leading to quick pulses of runoff. Currently, there is insufficient infrastructure to harness momentary surpluses of water, while impermeable surfaces or poor land use practices prevent much of the rain from infiltrating into the ground. In addition, levees may currently be too close to the stream to accommodate extreme rainfall or snowmelt events.



Increased temperatures could cause increased water demand. Higher temperatures will increase evaporation from open water surfaces and soils, thus increasing the demand for irrigation water while groundwater, mountain snowmelt and stream flow are likely to decline, especially when demand is highest.

Climate change could affect water quality. Increased evaporation from irrigated soils can lead to damaging and costly salinization.

Stakeholder Recommended Strategies:

Workshop participants discussed the importance of phasing adaptation strategies to account for the degree of certainty in future conditions. Improvements in land use planning, water use efficiency, pricing, land management and conservation, flood infrastructure and flood preparedness and education are strategies that provide extensive benefits regardless of future climate change impacts – these should be implemented first. More costly strategies (both economic and environmental) such as building new infrastructure should be considered in later phases as confidence in the need for such actions increases. Near-term strategies should keep future

adaptation options open – to ensure flexibility. Strategies that require more resources ought to be effective regardless of how the climate changes.

Improve stormwater management. Local governments should restore natural flood protection (floodplains, wetlands, etc.). Local governments should implement polices and programs to replace impermeable surfaces with permeable ones.

Levee systems and other flood control infrastructure should be maintained and upgraded where necessary. Regional water management and hazard mitigation plan policies should consider climate change, and be integrated into general plans.

Improve water supply management. Local governments should protect and restore prime areas that allow groundwater recharge and implement conjunctive use of surface water and groundwater. New basins should be constructed to increase recharge. Water supply should be monitored to develop a baseline, observe change over time, and fill in gaps. Local governments should implement programs and policies to increase conservation and efficiency of water use.

Water management plans such as the Upper Kings Basin Integrated Regional Water Management Plan, should be linked to general plans. Funding for monitoring should be secured. Floodplain management, water supply planning, wetland restoration efforts and land use planning should be integrated.

Conserve water. Local governments can promote water conservation by encouraging drought-tolerant landscaping/xeriscaping, working with the water districts to increase water storage (while supporting natural processes) and adjust water pricing (considering basic water needs versus "luxury use").

Local governments should implement best management practices from the California Urban Water Conservation Council (www.cuwcc.org/bmps.aspx) and the Ahwahnee Water Principles (http://water.lgc.org/guidebook).

Protect and restore ecosystems. Wetland, floodplain, and riparian ecosystems play a vital role in flood control, groundwater recharge and water quality through natural filtration and should be preserved. Key systems and corridors should be identified and mapped and an interregional collaborative should be developed to protect and restore these areas.

Key systems and corridors should be prioritized for conservation through land use planning, easements and habitat conservation plans. Funds should be leveraged by combining conservation projects with infrastructure and energy projects.

Improve water quality. Local governments should implement policies and regulatory programs to increase natural filtration by restoring/creating wetlands and floodplains to reduce runoff, regulate groundwater, improve the energy efficiency of municipal treatment facilities and develop new treatment options.

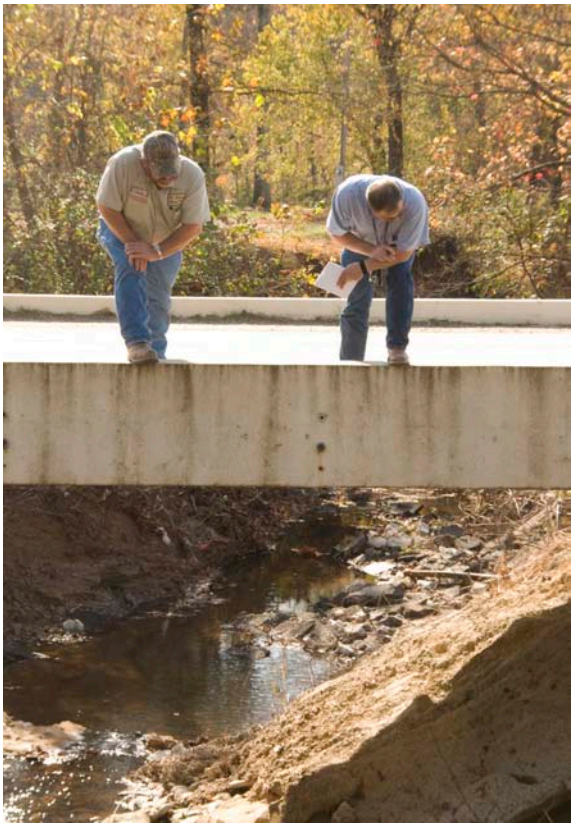
The appropriate measure to achieve ecosystem restoration will depend on who owns the land (private, local, state, federal).

4. Infrastructure

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

Potential Impacts:

Transportation routes are exposed to several climate change impacts. The main transportation infrastructure of the county – its roads, airport and railway – is susceptible in various ways to climate change impacts. These transportation routes are exposed to several climate-related risks, including heat extremes, flooding, increased wildfires and problems associated with soil erosion, sedimentation and landslides.



Climate change threatens energy related infrastructure. Two of the major power plants from which the county draws its power are located on the coast (Moss Landing and Diablo Canyon). While inland Fresno will not be directly exposed to the impacts of a rising sea level, both these coastal power plants are susceptible to sea-level rise-related risks such as flooding and coastal erosion in the future. In addition, snowmelt that feeds the reservoirs behind dams to create hydroelectric power is projected to decrease from climate change and shift in timing. According to a recent study undertaken for the State[21], high elevation hydropower generation clearly is expected to be impacted by climate change: "an increase in the occurrence of heat waves especially later in the summer period (September) would increase peak power demand at times when these systems might not be at peak power capacity unless operating strategies are modified." In 2009, Fresno saw a decline in hydropower due to the prolonged drought. Various small gas-fired plants provide supplemental electrical output, including a new Midway power plant about 15 miles southwest of Mendota in western Fresno County. The plants provide much needed energy to the region, but they also emit heat-trapping greenhouse gases that contribute to global warming.

Stakeholder Recommended Strategies:

Increase infrastructure maintenance and improvement. Local governments should follow the state plan using public purpose and various funding sources to implement improvements and maintenance at the local level through a mechanism that is coordinated among appropriate parties.

Conserve water and promote efficiency technology. Climate appropriate agriculture and landscape vegetation and water demand reduction should be encouraged. Water supply should be maintained through various means (incentives, legislation, regulatory, etc.) while also employing integrated demand-side management.

Water meters should be installed soon so the cost of water reflects its true cost. Changes to state and federal water laws should be advocated for.

Support public transit and alternative fuels vehicles. Local governments should implement livable community design principles, coordinate land use decisions, develop public transit infrastructure, and facilitate the use of alternative fuel vehicles and supporting infrastructure.

The county and cities within Fresno County should update their general plans, zoning codes, and ordinances and prioritize funding for public transit. Programs to educate the public and increase market demand for alternative fuel vehicles should also be implemented.

Preserve open space and avoid conversion to sprawl. The use of conservation easements should be increased. Development rights should be purchased for conservation. The Williamson Act should be supported and expanded.

Update and enforce codes for new and existing buildings. Local governments should enforce existing building codes and require that new buildings be constructed to meet green standards. Existing buildings should be retrofitted.

Local governments should enforce building codes, adopt a residential energy conservation ordinance and use incentives for public purpose change.

5. 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 often 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 disappearance, and even extinction. By the end of the century, 30% of all species worldwide could go extinct.[7] While native species are expected to decline with climate change, invasive non-native species could expand their ranges.

Workshop participants expressed a concern that climate change could, in concert with development, land use, and water use, cause an increasing number of listings of species as endangered and threatened. Listings come with associated costs and regulations that could limit economic activities. Proactive planning to address this concern by planning for natural habitats and connectivity concurrently while planning for regional growth would be one approach to reducing future listings while maintaining species, habitats, and ecosystem services that support a vibrant community. In addition, current conditions that already stress populations of fish, wildlife, and plants (e.g. habitat fragmentation, roads, pollution, sedimentation of waterways, grazing) will need to be lessened in order to allow species to persist as climate change stress increases over time.

…conditions that already stress populations of fish, wildlife, and plants (e.g. habitat fragmentation, roads, pollution, sedimentation of waterways, grazing) will need to be lessened in order to allow species to persist as climate change stress increases over time.

"Ecosystem Services," also called **"Nature's Benefits,"** are services or products, provided by intact ecosystems, that enhance our lives. Workshop participants were concerned with the potential collapse of many of these benefits due to climate change. In Fresno County, some important activities dependent on nature's benefits include:

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

Freshwater Aquatic and Riparian Systems

Potential Impacts:

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 the stream bed. Fisheries and endangered aquatic species are expected to decline. Additionally, grazing and other land use contribute to erosion and runoff.

Climate change may cause higher peak flows (during severe storms), extended low flows, warmer water, and reduced groundwater recharge. More extreme storm and flow conditions, as well as changes in the timing of flows, could have negative impacts on aquatic wildlife. Cold water fisheries could be impossible to recover without extreme measures, such as building cold water storage areas. Many valley floor species could be negatively impacted by sudden flooding, potentially wiping out entire populations of at-risk species during extreme events. Conversely, low flow periods could degrade floodplains, groundwater recharge areas, and associated habitats. Quick pulses of water will reduce recharge.

Lower average rainfall, higher evaporation, and increased sedimentation are expected to have negative impacts on vernal pools, wetlands, and riparian areas. Vernal pool and riparian species such as fairy shrimp, CA tiger salamander, CA red-legged frog, riparian brush rabbit, riparian woodrat, vernal pool plants, and Buena Vista Lake shrew are at risk. 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.

Many species and habitats are at risk from increased fragmentation in riparian and aquatic habitats from the compounding impacts of agriculture, development, and climate change. Vernal pools, riparian areas, and aquatic systems are expected to decline and become less connected, with potentially negative effects on wetland plant species (sensitive and common), rare invertebrate species, water birds, and others, specifically in Tule Lake, Buena Vista, Kern Lake as well as many lesser known vernal pools and wetlands.

Increased water demands for agriculture and communities could reduce water availability for aquatic species. Increased competition for water could lead to lower flows and disruption of aquatic migrations and fisheries. Water availability from the Delta is likely to be reduced at the same time that demand increases.

As climate change progresses, county planners may consider new dams or dam expansions, putting riparian areas at risk. Because Fresno County is highly reliant on water resources for agriculture and the local economy, the county will need to plan for sustainable water resources over the long term. Other parts of the state, such as Southern California, will also increase their pressure for water resources from limited Sierra snowpack.

Stakeholder Recommended Strategies:

Reduce water use. The first step would be to better understand where water is being used. The next step would be to implement conservation strategies, including:

- Enforce water meters sooner than the current mandated timeline
- Require increased efficiency from residential and agricultural users
- Develop new alternative water supplies (e.g., rainwater harvesting, greywater use, recycled water, etc.)
- Make better use of urban runoff
- Increase levels of water treatment

Reestablish natural surface water off-stream retention ponds and storage areas. In contrast to large water storage infrastructure projects, restoring dry lake beds, wetlands, vernal pools, backwaters, and floodplains allows for water storage and use without the high cost and negative ecological impacts. Dry lake beds (such as Tulare, Buena Vista, etc.) should be used for storing water for agriculture while also restoring important waterbird habitat and increasing groundwater recharge.

Restore proper function to floodplains and stream channels. By reconnecting, revegetating, and recontouring floodplains and stream channels, these systems should be used to provide water storage, groundwater recharge, sediment capture, and flood abatement. Such improvements would also provide essential habitat for aquatic and terrestrial species.

Restore and expand riparian areas along ALL lower elevation waterways. Riparian vegetation should be restored and expanded to increase shading, cool water temperatures, and provide cool refugia for wildlife,[22] thereby also providing movement corridors and breeding habitat. Levees should be moved further from streams and rivers to allow more riparian habitat and increase flood capacity.

Restore montane meadows, wetlands, and riparian areas. Montane meadows are important for holding spring runoff at high elevations, slowly releasing the water as stream flow throughout the summer months. These meadows were degraded by sheep and cattle grazing in the 19th and 20th centuries, but should be restored to offset some of the impacts of climate change. A showcase project is the Big Meadow Restoration Project on the Sequoia National Forest, which could be replicated in other areas. New wetlands could also be created using spring runoff, providing summer streamflow and groundwater recharge. Existing wetlands, riparian areas, and meadows should be protected for the ecosystem services.

Manage cold water aquatic systems. In order to preserve cold water systems, water storage and carefully timed releases may be necessary. Increased shading by restoring vegetation, as well as maintaining in-stream flow, will also be important.

Woodlands and Forests

Potential Impacts:

Regional forests could become a carbon source rather than a carbon sink. As the frequency, size, and severity of wildfire increases and mature native tree species decline, carbon will be released. Replacement with new trees or vegetation will result in a lag period of 80-100 years before comparable amounts of carbon can be stored. Continuously changing conditions could cause forests to remain in a state of flux, with mature trees that store large amounts of carbon becoming rare.

Oak woodland may decline substantially with continued development, increased disease, drought, and fire. Blue oaks and valley oaks are already stressed by habitat degradation and loss (resulting from development), drought, and competition from non-native annuals; they are also susceptible to high-frequency wildfire. Non-native grasses increase the spread and frequency of wildfire. Declines in oak habitat in the Sierra foothills would impact a great variety of species, including mule deer, mountain lion, bobcat, black bears, owls, woodpeckers, migrant songbirds, and numerous other species. These same areas were shown to be potential climate change "refugia" for native species[18], making them especially important for conservation.

Increased extent and severity of wildfire and drought could lead to a loss of coniferous forest and subalpine forest habitats. Climate change may act in concert with the legacy of forest management to affect fire size, frequency, severity, and duration. More severe fires, extended fire seasons, and more prolonged droughts could cause unprecedented tree mortality and a loss of regeneration. Uncharacteristic wildfires and drought could also impact giant sequoia groves, resulting in declines in abundance and distribution of this species throughout the Southern Sierra Nevada. Conversely, the increasing threat of fire could lead to actions intended to reduce fire risk, such as heavy thinning of sensitive habitats or in an ecologically unsound manner, with negative consequences for sensitive wildlife species (e.g., Pacific fisher, California spotted owl).

Declines in snowpack may lead to loss of tourism. Snowpack declines are expected to be severe, potentially leading to a loss of winter tourism. Snowpack is closely correlated to wildfire, and increased wildfire could cause a loss of summer tourism. Conversely, fall or spring tourism could remain viable.

Increases in pests, pathogens, and invasive species could threaten native species, ecological function, forestry, and tourism. As some native species decline, invasive species are expected to move in quickly. Invasive species could become dominant across the landscape and throughout aquatic systems (e.g., cheatgrass, quagga and zebra mussels). Some pests, such as native pine beetles, are expected to increase as trees become drought stressed. White bark pine could experience rapid declines due to a combination of warming temperatures, mountain pine beetle, and exotic white pine blister rust. Many activities increase the transport of invasive species, pests, and pathogens.

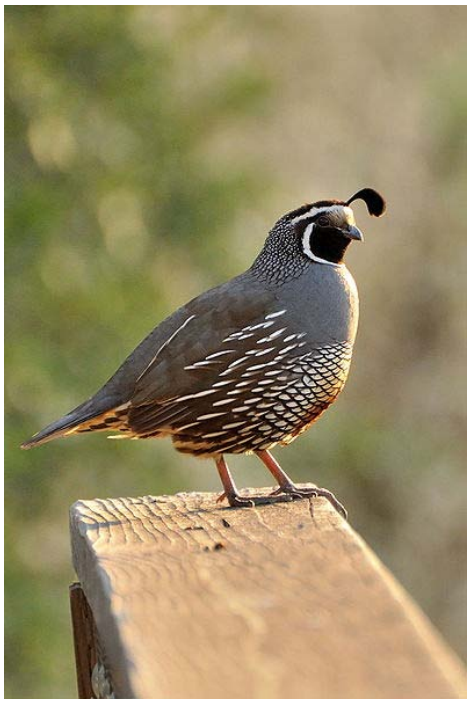
Recommended Strategies:

Manage for heterogeneity. Mid-elevation forests of the southern Sierra Nevada should be managed to increase forest heterogeneity at multiple spatial scales and reduce the density of small diameter shade-tolerant trees.[17] Best management practices that promote forest resilience and ecologically based management using a strategic landscape approach (less intensive thinning in localized cool and moist forests, more fuels management in south facing dry forests and more fire prone areas of the landscape) should be developed and shared with private land owners, along with support/incentives for implementation.

Reduce the chance of uncharacteristically severe wildfire. Strategic tools, such as controlled burns or grazing, should be used in an ecologically sound manner to increase the resilience of forests to climate change impacts. Fire management and prevention programs will need to be enhanced.

Implement rapid detection of and response to invasive species. The County should partner with the State and the Forest Service and Park Service to implement a system to address the threat of invasive species on public and private lands and coordinate this effort at a regional scale. Educating the public will also be a key part of the success of such a program.

Identify and protect future climate refuges and linkages for forest and woodland species. A recent framework for cooperative conservation and climate adaptation in the southern Sierras and Tehachapi range[18] demonstrates how climate model projections coupled with spatial data on land use planning and species ranges can be used to identify areas that are expected to become important refuges as climate change progresses. Linkages among current and future habitat patches will need to be maintained, allowing species to disperse to new areas. Areas identified for connectivity by the Tulare Basin Wildlife Partners (see www.tulare wildlifepartners.org) will become increasingly vital for native species persistence. Maintaining undeveloped elevational gradients to allow for upwards movement will also be important.



Strategic acquisition of sensitive lands and important habitat linkages should be pursued. Public agencies should explore conservation partnerships with private landowners to achieve the same ends. Foothill communities, especially those near blue oak and valley oak woodlands, should be targeted due to the threat of development and high importance for wildlife.

Multipurpose trails and corridor systems that incorporate riparian areas and other existing linear features (canals, railroad tracks, certain highways, etc.) should be developed.

Valley floor grasslands and semi-desert

Potential Impacts:

Many threatened and endangered species may be at increased risk. Protected species (e.g., blunt-nosed leopard lizard, San Joaquin kit fox, Tipton kangaroo rat) may be unable to shift to new areas as the climate changes due to a lack of linkages among valley floor refuges, especially further north. Some species might move to higher elevations to escape increasing temperatures (especially some plants), but others would be precluded due to low tolerance for hilly terrain (e.g., kit fox).

Some desert-adapted species could benefit from climate change. Some species, such as San Joaquin kit fox, blunt-nosed leopard lizard, kangaroo rats, San Joaquin antelope squirrel, Bakersfield cactus, and burrowing owls, may benefit if conditions become more arid. They could experience less competition from non-native invasive species and increased habitat availability due to retirement of marginal farmland and lower development pressure as people look for cooler temperatures. 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.

Aquatic systems on the valley floor are expected to decline as conditions become drier. Vernal pools, riparian areas, and dry lake beds are expected to become less common, with potentially negative effects on wetland plant species, rare invertebrate species (such as fairy shrimp), water birds, and others, specifically in Tule Lake, Buena Vista, Kern Lake as well as the large number of local vernal pools and wetlands that are not as well known.

San Joaquin kit fox
Photo courtesy of Brian Cypher

Stakeholder Recommended Strategies:

Map and conserve corridors that allow connectivity to other parts of the Central Valley and into the foothills. Parts of the western valley edge should especially be targeted for connectivity, allowing many species of special concern to shift to new areas as the climate becomes inhospitable to them in their current range. Corridors from the valley floor to the foothills, especially along rivers, should be restored with native riparian vegetation and protected to allow species to escape increasing temperatures and move to higher elevations or cooler microclimates (e.g., Deer Creek, Kings River, Kaweah River/Elk bayou, Tule River, and San Joaquin River have the best potential for corridors from valley flood to foothill). Land use on private lands and public lands should encourage restoration and conservation of riparian habitat. Connectivity should be planned at a regional, state, and multi-state scale.

Develop "Best Management Practices" (BMPs) for federal lands, with incentives for implementation on private lands. These practices should address carefully timed grazing, prescribed burning, restoration techniques and priorities (including planting), and protecting habitat in large, diverse blocks that allow for species to move to new areas while protecting multiple populations.

Improve agricultural practices. Organic farming techniques should be encouraged and modern chemical-based techniques improved to provide more habitat and clean water for native plants and animals. "Buffer strips" around agricultural land should be encouraged and expanded to provide habitat, decrease runoff, support beneficial insects, etc. (e.g., similar to Red Rock Ranch demonstration of salt management).

Consider restoration opportunities if farmland goes fallow. Many species on the valley floor are imperiled due to loss of habitat. As climate change progresses, these species could become more imperiled unless new habitat becomes available and conditions more favorable. As water resources become more scarce and temperature increases make some types of crops less productive in the region, lands that are currently used for farming may go fallow. The County, conservation groups, and USFWS should consider working together to target strategic lands for restoration to semi-desert or vernal pool habitat.

California jewelflower
Photo courtesy of Brian Cypher

SUGGESTED CHANGES TO GOVERNANCE AND PLANNING

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 to governance, decision making, budgeting, and managing may be needed. When managers are locked into 3-year, 5-year, or 15-year plans when unforeseen changes take place, effective response may be thwarted.

Changes to planning and governance that allow for flexibility in management approach should be clearly based on pre-defined decision making processes that are immune to short-term changes in leadership. For example, monitoring of wildfire conditions could trigger certain land use policy changes based on scientifically-determined trigger points. Without a clear decision-making process in place, increased flexibility is likely to be used as a political tool rather than as a sound management approach.

Greater access to shared information was requested by stakeholders. Information on climate change impacts, land use patterns, zoning changes, water yield, conservation priority areas, and other data, should all be made available in a common location. The availability of such information is expected to lead to more informed and scientifically-sound decisions on land and water management.

Stakeholders expressed their desire to see greater collaboration among diverse groups in land management across the county. Participation by

diverse groups in planning where and how land should be managed for specific needs and resources is important for reducing conflict. Water issues, especially, could be addressed in a collaborative manner that improves groundwater recharge, economic stability of agriculture, and natural systems resilience. By bringing groups together to tackle tough issues like water availability, the level of divisiveness and contention can to be replaced by teamwork directed towards a common goal.

Some workshop participants noted a lack of integration among the agencies responsible for the sectors impacted by climate change. Local governments should work with water districts, air districts, councils of government, public health departments, and federal landholders in the region to provide cohesive planning.

A number of potential policy improvements were identified to address existing barriers to adaptation. Policy changes 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 plans, integrated regional water management plans, hazard mitigation plans, regional transportation plans, State Implementation Plans and sustainable community strategy under SB 375.

Downtown Clovis

OPPORTUNITIES

Local governments can move forward despite uncertainty in projections by phasing adaptation strategies to account for the degree of certainty. For instance, temperature increases and associated snowpack declines are highly certain. In contrast, more uncertainty is associated with changes to precipitation. Improvements in land use planning, water and energy efficiency, land conservation, upgrades of flood infrastructure, disaster preparedness and education are strategies that should be top priority for implementation due to their benefits across sectors and regardless of climate change. Many of the more costly strategies, such as major infrastructure developments, should be avoided due to the uncertainty in projections as well as the great ecological costs.

Current opportunities for local government to address climate change adaptation include incorporating adaptation policies into existing planning efforts, changing zoning codes and ordinances to encourage smart growth and green building, increasing energy efficiency and renewable energy through programs like Energy Upgrade California and encouraging water conservation through ordinances, incentives and/or fees.

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. By managing for increased ecological resilience in the face of climate change, natural benefits will increase, thereby buffering human communities from the impacts of climate change.

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

Similarly, forest restoration that leads to reduced incidence of especially frequent or damaging fire could benefit ecological systems as well as

human populations. Fires within the historical range of intensity and frequency would be important to maintain, as they are integral to overall forest health. County governments may need to meet with federal fire ecologists to identify activities and actions for managing fire more cohesively throughout the county.

Quality of life – Preparing for climate change impacts involves changes to planning processes, infrastructure maintenance, food production, conservation prioritization, and many aspects of everyday life. These changes need to be made in light of climate change and other concurrent changes and stressors (e.g. population growth or land use practices). As 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 Fresno 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, to improve air quality for better health, 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.

CONCLUSIONS

Numerous changes to Fresno County and the surrounding counties are underway. Climate change presents an especially challenging influence because it is expected to worsen many existing stressors. Yet these challenges are surmountable with timely and adequate preparation.

The Fresno region encompasses a rich assortment of natural resources, diverse populations, local businesses, and agriculture of international importance. To maintain current features of the region, solve current issues of importance, and remain vibrant and sustainable as the climate changes, the County will need to increase the resilience of both natural and human communities.

Changes in the way the County manages the landscape, makes decisions, and works across jurisdictions may be necessary. In fact, climate change may be such a severe threat to the local economy, human health, safety, and ecological function that a new governance structure may need to be implemented. Rather than planning for continued historical conditions, a major shift in approach to plan for uncertain and changing conditions will need to be adopted.

The County and the cities within it can begin by building off the vision created through the Fresno County Blueprint. Additionally a $4 million grant from HUD will fund complementary work through a collaboration of 14 major cities in the San Joaquin Valley. This effort, Smart Valley Places, will include a range of planning efforts including: Greenhouse Gas Emissions Inventories, Climate Action Plans and implementation; Planning & Impact Assessment Tools; and updates to general plans, development codes, Watershed Stewardship Plans, and Master Infrastructure Plans. There is an opportunity to integrate the adaptation strategies discussed in the report into those efforts. By integrating climate change adaptation with ongoing mitigation efforts, the County and cities within 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 can save money, increase communication and collaboration among disparate groups, reduce conflict, and ultimately save lives and prevent suffering.

While difficult choices will need to be made, the County has the opportunity to thrive by planning early for changing conditions. Adaptation efforts carefully vetted against other policy goals, including greenhouse gas mitigation efforts, pose an important opportunity to move toward greater long-term resilience, independence, and sustainability.

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
Implement "Smart growth" policies	Reduces sprawl into natural areas	Consolidates emergency response needs into a smaller area	Provides a local market for fresh produce and other products	Reduces per capita water and energy use	Low impact design	Reduces per capita greenhouse gas emissions
Reduce water 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	Less wear on water infrastructure	Less energy use for water treatment and distribution
Identify and conserve climate "refuges" for wildlife and plants	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	

LITERATURE CITED

[1]Cayan, D., M. Tyree, M. Dettinger, H. Hidalgo, T. Das, E. Maurer, P. Bromirski, N. Graham, and R. Flick. 2009. Climate Change Scenarios and Sea Level Rise Estimates for California 2008 Climate Change Scenarios Assessment. California Climate Change Center. CEC- 500-2009-014-F.

[2]Westerling, A. L., H. G. Hidalgo, D. R. Cayan, and T. W. Swetnam. 2006. Warming and earlier spring increase Western U.S. forest wildfire activity. Science 313: 940-943.

[3]Root, T. L., J. T. Price, K. R. Hall, S. H. Schneider, C. Rosenweig, and J. Alan Pounds. 2003. Fingerprints of global warming on wild animals and plants. Nature 421: 57-60.

[4]Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. R. K. Pacharui and A. Reisinger, eds. Geneva, Switzerland. (www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm)

[5]U.S. Global Change Research Program. 2009. Global Climate Change Impacts in the United States. T. R. Carl, J. M. Mellilo, and T. C. Peterson, eds. Cambridge University Press.

[6]Bender, M. A., T. R. Knutson, R. E. Tuleya, J. J. Sirutis, G. A. Vecchi, S. T. Garner, I. M. Held. 2010. Modeled Impact of Anthropogenic Warming on the Frequency of Intense Atlantic Hurricanes. Science 327:454-458.

[7]Thomas, C. D., A. Cameron, R. E. Green, M. Bakkenes, L. J. Beaumont, et al. 2004. Extinction risk with climate change. Nature 427:145-148.

[8]Raupach, M. R., G. Marland, P. Ciais, C. Le Quéré, J. G. Canadell, G. Klepper, and C. B. Field. 2007. Global and regional drivers of accelerating CO_2 emissions. PNAs 104:10288-10293.

[9]Randall, D.A., et al. Climate Models and Their Evaluation. *In* Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Eds. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Avery, T. M. Tignor and H. L. Miller. Cambridge University Press. Cambridge, United Kingdom and New York, USA.

[10]Koopman, M. E., R. S. Nauman, and J. L. Leonard. 2010. Future Climate Conditions in Fresno County and Surrounding Counties. The National Center for Conservation Science and Policy. (www.geosinstitute.org/images/stories/pdfs/Publications/ClimateWise/FresnoModelReportFINAL.pdf)

[11]Millstein, D. E. and R. A. Harley. 2009. Impact of Climate Change on Photochemical Air Pollution in Southern California - Final Report. California Climate Change Center. CEC-500-2009-021-F.

[12]Leung, L. R., W. I. Gustafson, Jr. 2005. Potential regional climate change and impacts to U. S. air quality. Geophysical Research Letters 32:L16711.

[13]Mintier Harnish. 2010. San Joaquin Valley Blueprint Planning Process: Summary Report. (http://www.fresnocog.org/files/Blueprint/SJVBR_Summary_Final_2010-09-22.pdf)

[14]Council of Fresno County Governments. 2009. San Joaquin Valley Blueprint: Fresno County Progress Report. (http://www.fresnocog.org/files/Blueprint/ProgressReport/Fresno%20County%20BP%20Document%20Revised%20Final%2007_27_09.pdf)

[15]Harmsen, F., D. Hunsaker, P. Van de Water, and Y. V. Luo. 2009. Mitigation and Adaptation Strategies for Climate Change in Fresno California. Institute for Climate Change, Oceans, and Atmosphere. CSU Fresno. (http://www.csufresno.edu/icoa/projects/fresnoclimate.shtml)

[16]Tulare Basin Wildlife Partners. 2010. Tulare Basin Conservation Plan Water Supply Strategies Report. (see www.tularebasinwildlifepartners.org)

[17]North, M., P. Stine, K. O'Hara, W. Zielinski, and S. Stephens. 2009. An ecosystem management strategy for Sierran mixed-conifer forests. Gen. Tech. Rep. PSW-GTR-220. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 49 p.

[18]Southern Sierra Partnership. 2010. Framework for Cooperative Conservation and Climate Adaptation for the Southern Sierra Nevada and Tehachapi Mountains. (http://conserveonline.org/workspaces/climateadaptation/documents/southern-sierra-partnership-ca-0)

[19]American Farmland Trust. 2010. California Agricultural Report: Strategies for Sustainability. California Dept. of Food and Agriculture and State Board of Food and Agriculture. (http://www.cdfa.ca.gov/agvision/)

[20]Moser, S. and J. Ekstrom. 2010. Toward a Vibrant, Prosperous and Sustainable Fresno County: Vulnerability and Adaptation in the Midst of Rapid Change. Technical Report. Susanne Moser Research & Consulting, Santa Cruz, CA. (http://www.lgc.org/adaptation/fresno/)

[21]Vicuña, S., J. A. Dracup, and L. Dale. 2009. Climate Change Impacts on the Operation of Two High-Elevation Hydropower Systems in California. California Energy Commission. CEC-500-2009-019-D Sacramento, CA.

[22]Seavy, N. E., T. Gardali, G. H. Golet, F. T. Griggs, C. A. Howell, T. R. Kelsey, S. Small, J. H. Viers, J. F. Weigand. 2009. Why climate change makes riparian restoration more important than ever. *Ecological Restoration* 27:330-338.