Chapter 1

Summary for Decision Makers

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With contributions from the authors of this assessment report

1.1 Introduction

Natural climate variability is a prominent factor that affects many aspects of life, livelihoods, landscapes, and decision-making across the Southwestern U.S. (Arizona, California, Colorado, Nevada, New Mexico, and Utah; included are the adjacent United States-Mexico border and Southwest Native Nations land). These natural fluctuations have caused droughts, floods, heat waves, cold snaps, heavy snow falls, severe winds, intense storms, the battering of coastal areas, and acute air-quality conditions. And as a region that has experienced—within the relatively short time span of several decades—rapid increases in human population (Figure 1.1), significant alterations in land use and land cover, limits on the supplies of water, long-term drought, and other climatic

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changes, the Southwest can be considered to be one of the most "climate-challenged" regions of North America. This document summarizes current understanding of climate variability, climate change, climate impacts, and possible solution choices for the climate challenge, all issues that are covered in greater depth in *Assessment of Climate Change in the Southwest United States.*[i]

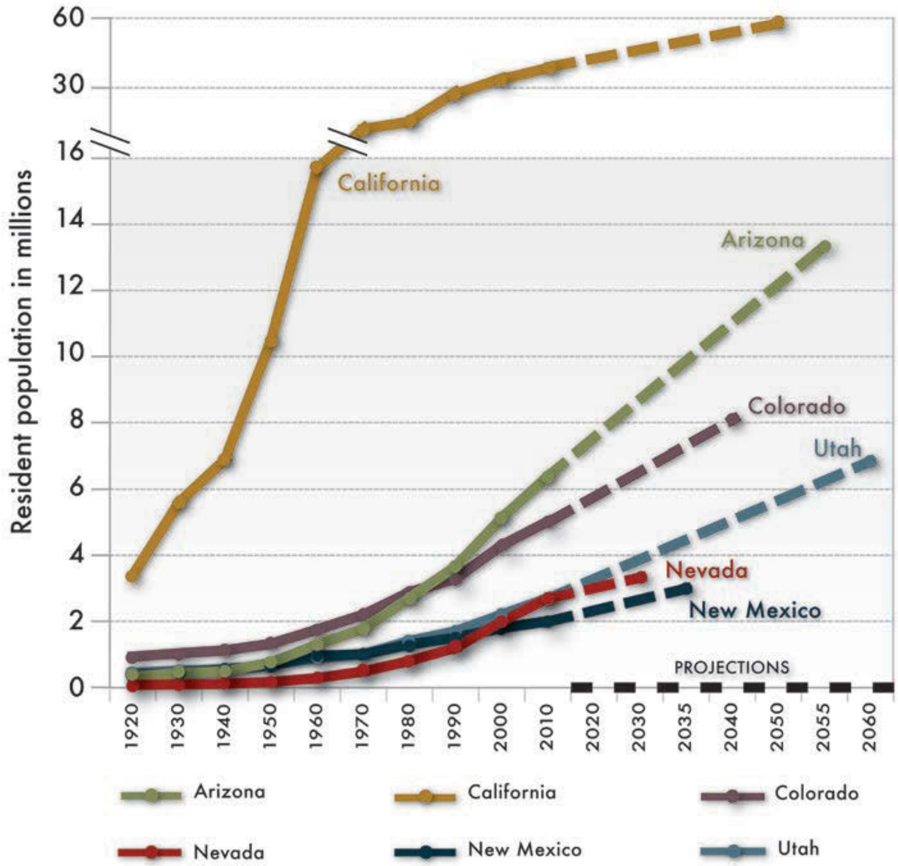

Figure 1.1 Rapid population growth in the Southwest is expected to continue. The current (2010) population is 56 million, and an additional 19 million people are projected to be living in the region by 2030. Source: US Department of Commerce, Bureau of Economic Analysis http://www.bea.gov/regional/index.htm. [Chapter 3]

The juxtaposition of the Southwest's many landscapes—mountains, valleys, plateaus, canyons, and plains—affect both the region's climate and its response to climate change. Whether human and natural systems are able to adapt to changes in climate will be influenced by many factors, including the complex topographic pattern of land ownership and the associated policies and management goals. Moreover, the human population in the region will likely grow, primarily in urban areas, from a population of about 56 million in 2010 to an estimated 94 million by 2050 (Figure 1.1). [Chapter 3]

The Southwest climate is highly variable across space and over time related to such factors as ocean-land contrasts, mountains and valleys, the position of jet streams, the North American monsoon, and proximity to the Pacific Ocean, Gulf of California, and

Gulf of Mexico. The Mojave and Sonoran Deserts of Southern California, Nevada, and Arizona are the hottest (based on July maximum temperatures), driest regions of the contiguous United States. Coastal zones of California and northwestern Mexico have large temperature gradients and other properties from the shore to inland. Mountain regions are much cooler and usually much wetter regions of the Southwest, with the Sierra Nevada and mountains of Utah and Colorado receiving nearly half of their annual precipitation in the form of snow. The resulting mountain snowpack provides much of the surface water for the region, in the form of spring runoff. [Chapter 4]

There is mounting scientific evidence that climate is changing and will continue to change. There is also considerable agreement—at varying levels of confidence sufficient to support decision making—regarding why the climate is changing, or will change [Chapter 19]. Readers of this summary may wish to review all or parts of the complete report, *Assessment of Climate Change in the Southwest United States*, to learn more about the region's climate, and its likely changes and effects.

1.2 Observed Recent Climatic Change in the Southwest

The climate of the Southwest is already changing in ways that can be attributed to human-caused emissions of greenhouse gases, or that are outcomes or expressions consistent with such emissions—with these notable observations:

- ***The Southwest is warming***. Average daily temperatures for the 2001–2010 decade were the highest (Figure 1.2) in the Southwest from 1901 through 2010. Fewer cold waves and more heat waves occurred over the Southwest during 2001–2010 compared to average decadal occurrences in the twentieth century. The period since 1950 has been warmer than any period of comparable length in at least 600 years, as estimated on the basis of paleoclimatic tree-ring reconstructions of past temperatures. [Chapter 5]
- ***Recent drought has been unusually severe relative to droughts of the last century, but some droughts in the paleoclimate record were much more severe***. The areal extent of drought over the Southwest during 2001–2010 was the second largest observed for any decade from 1901 to 2010. However, the most severe and sustained droughts during 1901–2010 were exceeded in severity and duration by multiple drought events in the preceding 2,000 years (Figure 1.3). [Chapter 5]
- ***Recent flows in the four major drainage basins of the Southwest have been lower than their twentieth century averages.*** Streamflow totals in the Sacramento-San Joaquin Rivers, Upper Colorado, Rio Grande, and Great Basin were 5% to 37% lower during 2001–2010 than their twentieth century average flows. Moreover, streamflow and snowmelt in many snowmelt-fed streams of the Southwest tended to arrive earlier in the year during the late twentieth century than earlier in the twentieth century, and up to 60% of the change in arrival time has been attributed to increasing greenhouse-gas concentrations in the atmosphere (Figure 1.4). [Chapter 5]

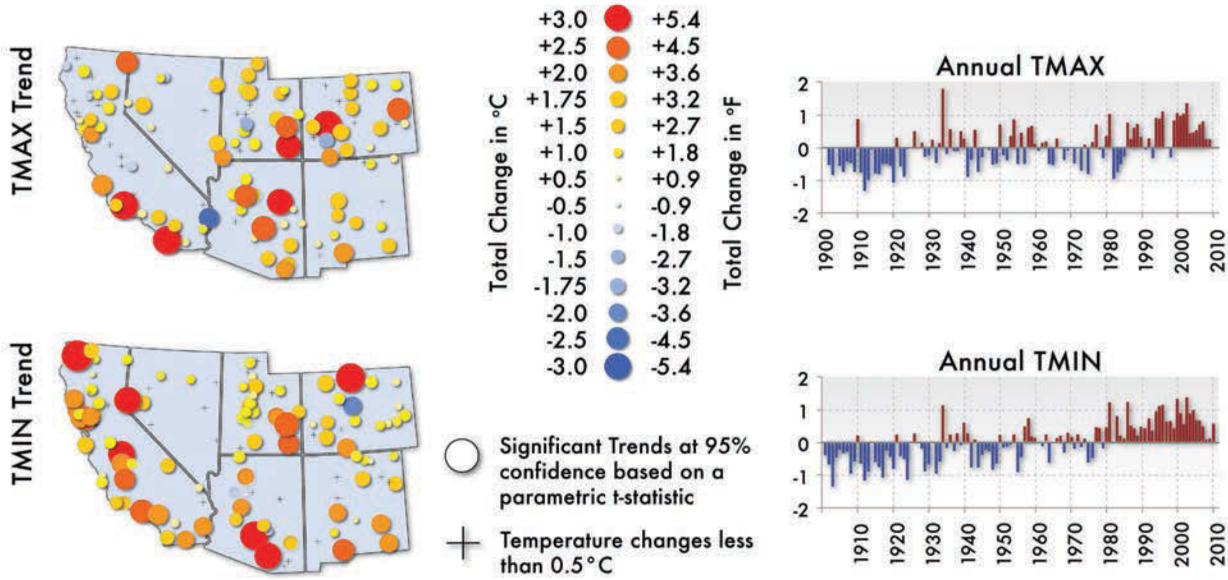

Figure 1.2 Temperature trends in the twentieth century. The 1901–2010 trends in annually averaged daily maximum temperature (TMAX, top) and daily minimum temperature (TMIN, bottom). Units are the change in °C/110yrs. Trends computed from 251 stations for precipitation analysis and 180 stations for temperature analysis using GHCN V3 data. Source: Menne and Williams (2009). [Chapter 5]

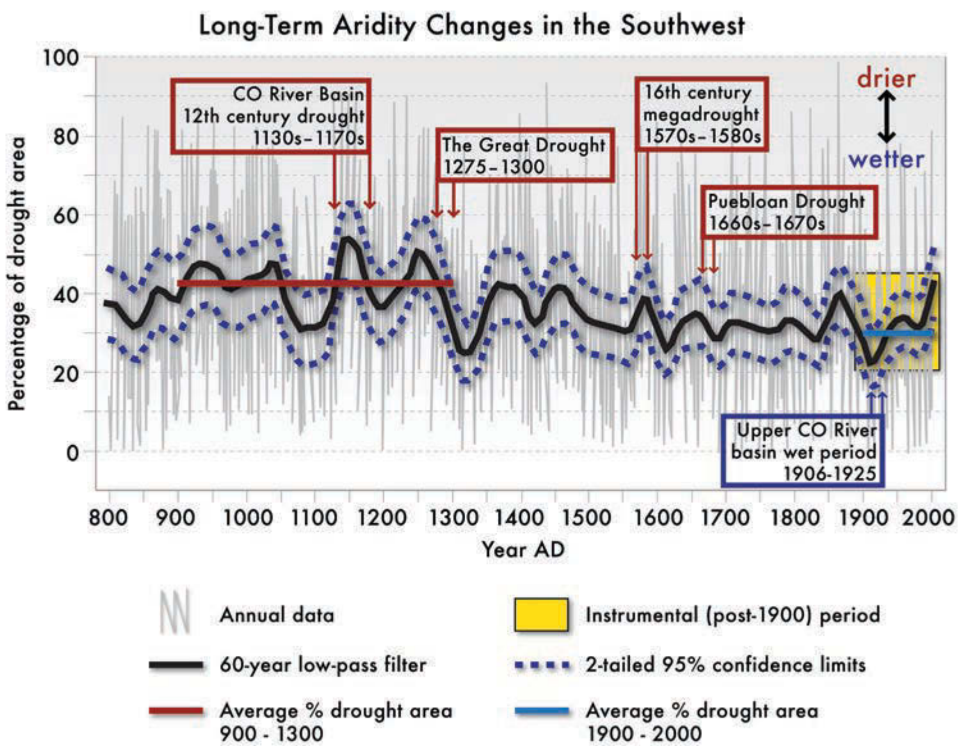

Figure 1.3 History of drought in the West. Percent area affected by drought (PDSI<–1) across the western United States, as reconstructed from tree-ring data. Modified from Cook et al. (2004), reprinted with permission from the American Association for the Advancement of Science. [Chapter 5]

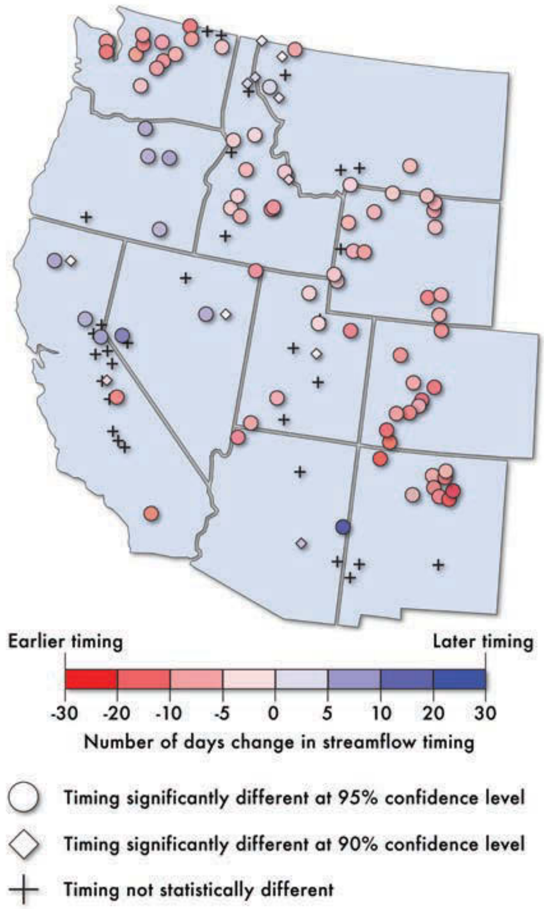

Figure 1.4 Changing streamflow timing 2001–2010 compared to 1950–2000. Differences between 2001–2010 and 1950–2000 average date when half of the annual streamflow has been discharged (center of mass) for snowmelt-dominated streams (Stewart, Cayan and Dettinger 2005). [Chapter 5]

1.3 Projected Future Climatic Change in the Southwest

Climate scientists have high confidence that the climate of the Southwest will continue to change through the twenty-first century and beyond, in response to human-generated greenhouse gas emissions, and will continue to vary in ways that can be observed in historic and paleoclimate records (Table 1.1). However, not all aspects of the climate change or variation can be projected with equal confidence.[ii] The highest confidence is associated with projections that are consistent among climate models and with observed changes, such as those described in the previous section. The magnitude and duration of future change depends most on the amount of greenhouse gases emitted to the atmosphere, particularly carbon dioxide emitted by the burning of coal, oil, and natural gas. Much of the future change will be irreversible for centuries after substantial anthropogenic carbon dioxide emissions have ceased.

- ***Warming will continue, with longer and hotter heat waves in summer.*** Surface temperatures in the Southwest will continue to increase substantially over the twenty-first century (high confidence), with more warming in summer and fall than winter and spring (medium-high confidence) (Figures 1.5 and 1.6). Summer heat waves will become longer and hotter (high confidence). Winter cold snaps will become less frequent but not necessarily less severe (medium-high confidence). [Chapter 6 and 7]

- ***Average precipitation will decrease in the southern Southwest and perhaps increase in northern Southwest.*** Precipitation will decline in the southern portion of the Southwest region, and change little or increase in the northern portion (medium-low confidence) (Figure 1.6). [Chapter 6]
- ***Precipitation extremes in winter will become more frequent and more intense (i.e., more precipitation per hour)*** (medium-high confidence). Precipitation extremes in summer have not been adequately studied. [Chapter 7]
- ***Late-season snowpack will continue to decrease***. Late winter-spring mountain snowpack in the Southwest will continue to decline over the twenty-first century, mostly because temperature will increase (high confidence) (Figure 1.7). [Chapter 6]
- ***Declines in river flow and soil moisture will continue.*** Substantial portions of the Southwest will experience reductions in runoff, streamflow, and soil moisture in the mid- to late-twenty-first century (medium-high confidence) (Figure 1.7). [Chapter 6]
- ***Flooding will become more frequent and intense in some seasons and some parts of the Southwest, and less frequent and intense in other seasons and locations***. More frequent and intense flooding in winter is projected for the western slopes of the Sierra Nevada (medium-high confidence), whereas snowmelt-driven spring and summer flooding could diminish in that mountain range (high confidence). [Chapter 7]
- ***Droughts in parts of the Southwest will become hotter, more severe, and more frequent*** (high confidence). Drought, as defined by Colorado River flow amount, is projected to become more frequent, more intense, and more prolonged, resulting in water deficits in excess of those during the last 110 years (high confidence). However, northern Sierra Nevada watersheds may become wetter with climate change (low confidence). [Chapter 7]

1.4 Recent and Future Effects of Climatic Change in the Southwest

Terrestrial and freshwater ecosystems

Natural ecosystems are being affected by climate change in noticeable ways, which may lead to their inhabitants needing to adapt, change, or move:

- ***The distributions of plant and animal species will be affected by climate change***. Observed changes in climate are associated strongly with some observed changes in geographic distributions of species in the Southwest (high confidence). [Chapter 8]

Table 1.1 Current and predicted climate phenomena trends discussed in this report

Projected Change Parameter	Direction of Change	Is it Occurring?	Remarks	Confidence	Chapter
Average annual temperature	Increase	Yes. Southwest temperatures increased 1.6°F +/- 0.5°F, between 1901-2010.	Depending on the emissions scenario, model projections show average annual temperature increases of 1-4°F in the period 2021-2050, 1-6°F in 2041-2070, and 2-9°F in 2070-2099. Changes along the coastal zone are smaller than inland areas.	High	5; 6
Seasonal temperatures	Increase	Yes, in all seasons. Studies conclusively demonstrate partial human causation of winter/spring minimum temperature increases.	Model projections show the largest increases in summer and fall. The largest projected increases range from 3.5°F in the period 2021-2050 to 9.9°F in 2070-2099.	High	5; 6
Freeze-free season length	Increase	Yes, the freeze-free season for the Southwest increased about 7% (17 days) during 2001–2010 compared to the average season length for 1901–2000.	Model projections using a high emissions scenario (A2) show that by 2041–2070, most of the region exhibits increases of at least 17 freeze-free days, with some parts of the interior showing 38-day increases.	High	5; 6
Heat waves	Increase	Yes. More heat waves occurred over the Southwest during 2001–2010 compared to average occurrences in the twentieth century.	Model projections show an increase in summer heat wave frequency and intensity.	High	5; 7
Cold snaps	Decrease	Fewer cold waves occurred over the Southwest during 2001–2010 compared to average occurrences in the twentieth century.	Winter time cold snaps are projected to diminish their frequency but not necessarily their intensity into late century. Interannual and decadal variability will modulate occurrences across the region.	Medium-high	5; 7

Table 1.1 Current and predicted climate phenomena trends discussed in this report (Continued)

Projected Change Parameter	Direction of Change	Is it Occurring?	Remarks	Confidence	Chapter
Average annual precipitation	Decrease	Not yet detectable. During 1901–2010 there was little regional change in annual precipitation.	For all periods and both scenarios, model simulations show both increases and decreases in precipitation. For the region as a whole, most of the median values are negative, but not by much, whereas the range of changes, among different models, is high. Annual precipitation projections generally show decreases in the southern part of the region and increases in the northern part.	Medium-low	6
Spring precipitation	Decrease	Not yet detectable.	By mid-century, all but one model projects spring regional precipitation decreases. By 2070-2099, the median projected decrease is 9-29%, depending on the emissions scenario.	Medium-high	6
Extreme daily precipitation	Increase	Maybe. Studies indicate the frequency of extreme daily precipitation events over the Southwest during 1901–2010 had little regional change in extreme daily precipitation events.	Models project more intense atmospheric river precipitation; some studies project more frequent intense precipitation during the last half of the twenty-first century, especially in the northern part of the region.	Medium-low	5; 7
Mountain snowpack	Decrease	Yes, in parts of the Southwest.	Model projections from this report and other studies project a reduction of late winter-spring mountain snowpack in the Southwest over the twenty-first century, mostly because of the effects of warmer temperature.	High	6

Table 1.1 Current and predicted climate phenomena trends discussed in this report (Continued)

Projected Change Parameter	Direction of Change	Is it Occurring?	Remarks	Confidence	Chapter
Snowmelt and streamflow timing	Earlier	Yes, snowmelt and snowmelt-fed streamflow in many streams of the Southwest trended towards earlier arrivals in the late-twentieth century and early twenty-first century.	Not analyzed in this report, but implied by projections of diminished April 1 snow water equivalent in most Southwest river basins.	High	5, 6
Flooding	Increase	No. Annual peak streamflow rates declined from 1901 to 2008 in the Southwest.	More frequent and intense flooding in winter is projected for the western slopes of the Sierra Nevada range; Colorado Front Range flooding in summer is projected to increase.	Low	5; 7
Drought severity	Increase	Yes. During the period 1901-2010. However, the most severe and sustained droughts during 1901–2010 were exceeded in severity and duration by drought events in the preceding 2000 years.	Observed Southwest droughts have been exacerbated by anomalously warm summer temperatures. Model projections of increased summer temperatures would exacerbate future droughts. Model projections show depletion of June 1 soil moisture and lower total streamflow.	Medium-high	5; 6

- ***Ecosystem function and the functional roles of resident species will be affected***. Observed changes in climate are associated strongly with some observed changes in the timing of seasonal events in the life cycles of species in the region (high confidence). [Chapter 8]
- ***Changes in land cover will be substantial***. Observed changes in climate are affecting vegetation and ecosystem disturbance (Figure 1.8). Among those disturbances are increases in wildfire and outbreak of forest pests and disease. Death of plants in some areas of the Southwest also is associated with increases in temperature and decreases in precipitation (high confidence). [Chapter 8]
- ***Climate change will affect ecosystems on the U.S.-Mexico border***. Potential changes to ecosystems that transect the international border are often not explicitly considered in the public policy exposing these sensitive ecosystems to climate change impacts (high confidence). [Chapter 16]

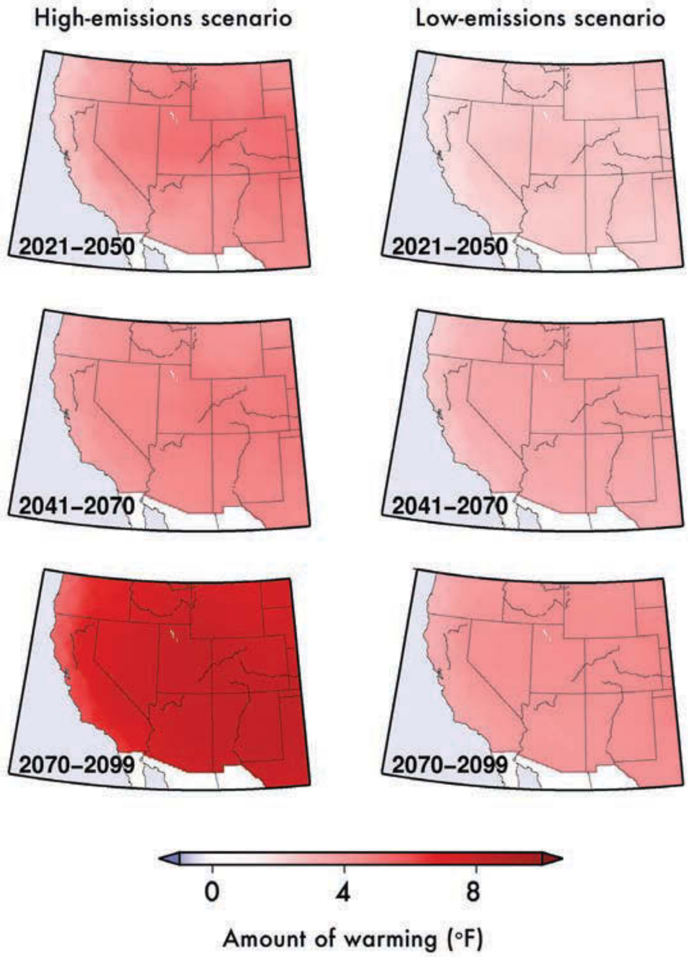

Figure 1.5 Projected temperature changes for the high (A2) and low (B1) GHG emission scenario models. Annual temperature change (°F) from historical (1971–2000) for early- (2021–2050; top), mid- (2041–2070; middle) and late- (2070–2099; bottom) twenty-first century periods. Results are the average of the sixteen statistically downscaled CMIP3 climate models. Source: Nakićenović and Swart (2000), Mearns et al. (2009). [Chapter 6]

Coastal systems

Coastal California is already being affected by climate change, and future climate-related change will become more notable if greenhouse-gas emissions are not substantially reduced:

- ***Coastal hazards, including coastal erosion, flooding, storm surges and other changes to the shoreline will increase in magnitude as sea level continues to rise*** (high confidence). Sea levels along the California coast have risen less than a foot since 1900, but could rise another two feet (high confidence), three feet (medium-high confidence), or possibly more (medium-low confidence) by the end of the twenty-first century (Figure 1.9). [Chapter 9]
- ***Effects of coastal storms will increase***. Increased intensity (medium-low confidence) and frequency (medium-low confidence) of storm events will further change shorelines, near-shore ecosystems, and runoff. In many regions along the

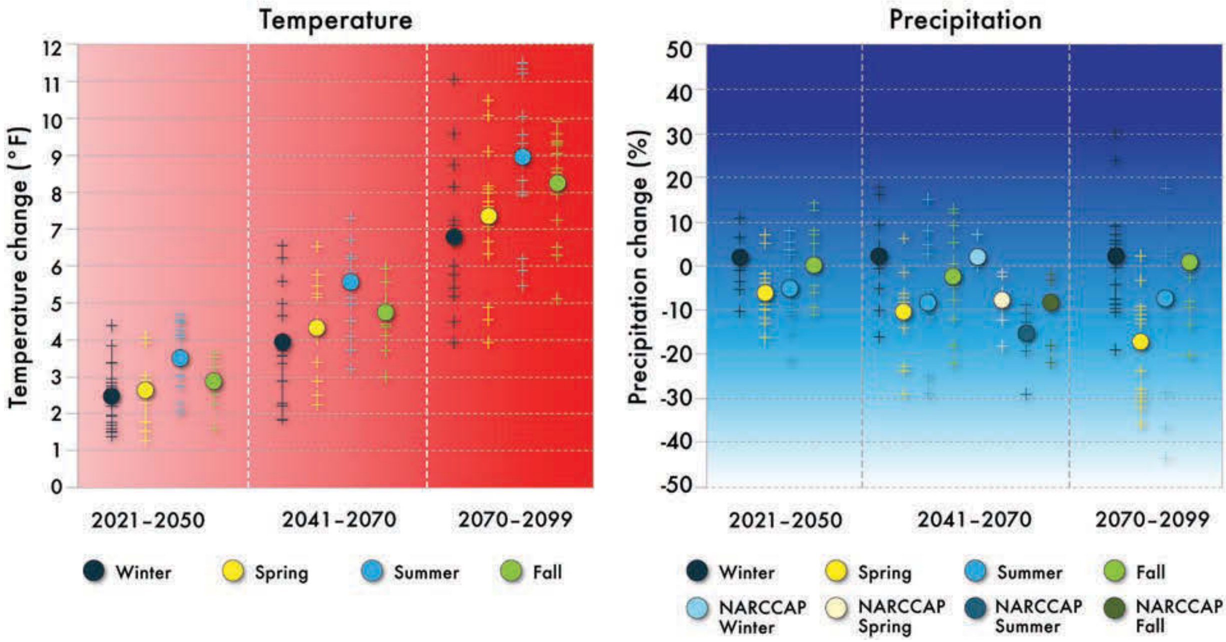

Figure 1.6 Projected change in average seasonal temperatures (°F, left) and precipitation (% change, right) for the Southwest region for the high-emissions (A2) scenario. A fifteen-model average of mean seasonal temperature and precipitation changes for early-, mid-, and late-twenty-first century with respect to the simulations' reference period of 1971–2000. Changes in precipitation also show the averaged 2041–2070 NARCCAP four global climate model simulations. The seasons are December–February (winter), March–May (spring), June–August (summer), and September–November (fall). Plus signs are projected values for each individual model and circles depict overall means. Source: Mearns et al. (2009). [Chapter 6]

coast, storms coupled with rising sea levels will increase the exposure to waves and storm surges (medium-high confidence). [Chapter 9]

- *Economic effects of coastal climate change will be large*. Between 2050 and 2100, or when sea levels are approximately 14–16 inches higher than in 2000, the combined effects of sea-level rise and large waves will result in property damage, erosion, and economic losses far greater than currently experienced (high confidence). [Chapter 9]
- ***Coastal ecosystems and their benefits to society will be affected.*** Ocean warming, reduced oxygen content, and sea-level rise will affect marine ecosystems, abundances of fishes, wetlands, and coastal communities (medium-high confidence). However, there is uncertainty in how and by how much coastal ecosystems will be affected. [Chapter 9]
- *Ocean acidification is taking place*. Many marine ecosystems will be negatively affected by ocean acidification that is driven by increased levels of atmospheric carbon dioxide (high confidence). But there is substantial uncertainty about the effects of acidification on specific coastal fisheries and marine food webs. [Chapter 9]

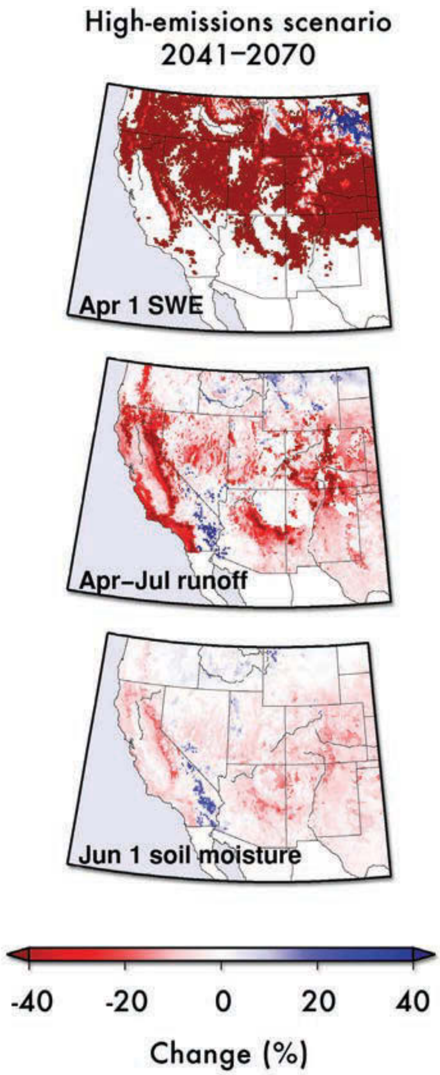

Figure 1.7 Predicted changes in the water cycle. Mid-century (2041–2070) percent changes from the simulated historical median values from 1971–2000 for April 1 snow water equivalent (SWE, top), April–July runoff (middle) and June 1 soil moisture content (bottom), as obtained from median of sixteen VIC simulations under the high-emissions (A2) scenario. Source: Bias Corrected and Downscaled World Climate Research Programme's CMIP3 Climate Projections archive at http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/#Projections:%20Complete%20Archives. [Chapter 6]

Water

Water is the limiting resource in the Southwest, and climate variability and change will continue to have substantial effects on water across much of the region. Reduction in water supplies can lead to undesirable changes in almost all human and natural systems including agriculture, energy, industry, forestry, and recreation. In particular:

- ***Climate change could further limit water availability in much of the Southwest.*** A large portion of the Southwest, including most of the region's major river systems (e.g., Rio Grande, Colorado, and San Joaquin), is expected to experience reductions in streamflows and other limitations on water availability in the twenty-first century (medium-high confidence) (Figure 1.7). [Chapters 5, 6, 7, and 10]

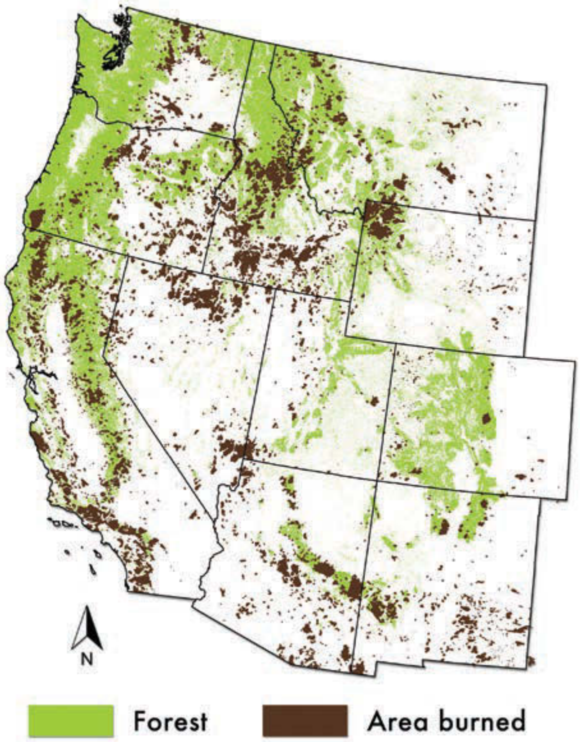

Figure 1.8 Areas of the western United States burned in large (> 1000 acres [400 ha]) fires, 1984–2011. Dark shading shows fires in areas classified as forest or woodland at 98-feet (30-meter) resolution by the LANDFIRE project (http://www.landfire.gov/). Fire data from 1984–2007 are from the Monitoring Trends in Burn Severity project (http://www.mtbs.gov/) and fire data from 2008–2011 are from the Geospatial Multi-Agency Coordination Group (http://www.geomac.gov/). [Chapter 8]

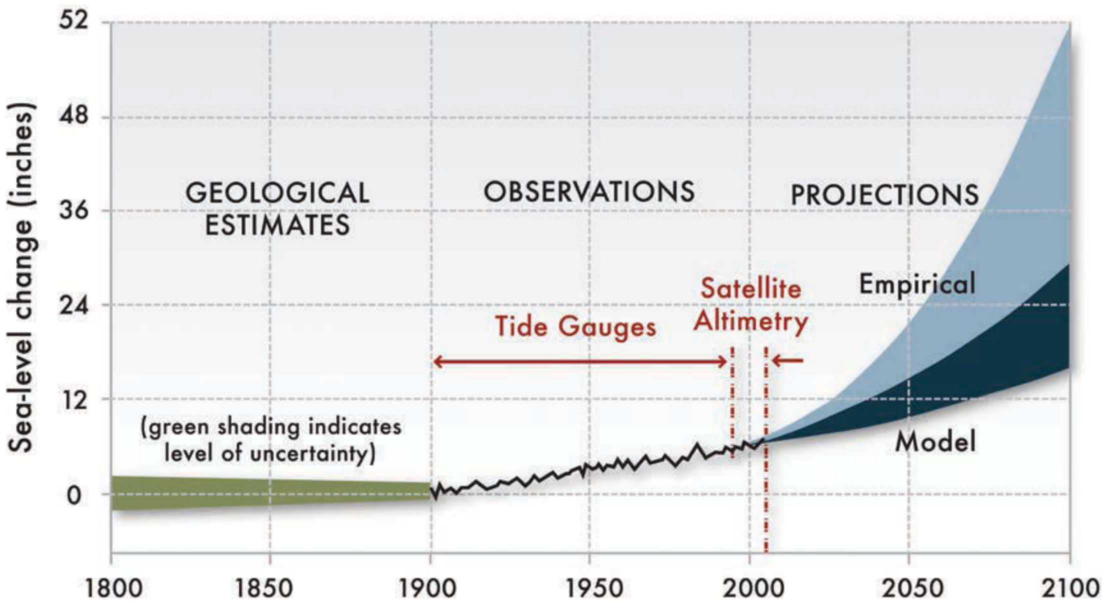

Figure 1.9 Past, present, and future sea-level rise. Geologic and recent sea-level histories (from tide gauges and satellite altimetry) are combined with projections to 2100 based on climate models and empirical data. Modified with permission from Russell and Griggs (2012), Figure 2.1. [Chapter 9]

- ***Water availability could be decreased even more by unusually warm, decades-long periods of drought***. Much of the Southwest, including major river systems such as the Colorado and Rio Grande, has experienced decades-long drought repeatedly over the last 1,000 to 2,000 years. Similar exceptional droughts could occur in the future, but temperatures are expected to be substantially hotter than in the past (high confidence) (Figure 1.3). [Chapters 5, 6, 7, and 10]
- ***The past will no longer provide an adequate guide to project the future***. Twentieth-century water management has traditionally been based in part on the principle of "stationarity," which assumes that future climate variations are similar to past variations. As climate changes, temperature will increase substantially and some areas of the Southwest will become more arid than in the past (high confidence). [Chapters 6 and 10]
- ***Surface water quality will be affected by climate change.*** In some areas, surface water quality will be affected by scarcity of water, higher rates of evaporation, higher runoff due to increased precipitation intensity, flooding, and wildfire (high confidence). [Chapter 10]

Human health

The Southwest's highly complex and often extreme geography and climate increase the probability that climate change will affect public health. Several potential drivers of increased health risk exist only or primarily in the Southwest, and there is substantial variation in the sensitivity, exposure, and adaptive capacity of individuals and groups of people within the Southwest to climate change-related increases in health risks:

- ***Climate change will drive a wide range of changes in illness and mortality***. In particular, climate change will exacerbate heat-related human morbidity and mortality, and lead to increased concentrations of airborne particulates and pollutants from wildfires and dust storms. Climate change may affect the extent to which organisms such as mosquitoes and rodents can carry pathogens (e.g., bacteria and viruses) and transmit disease from one host to another (medium-high confidence). [Chapter 15]
- ***Allergies and asthma will increase in some areas***. On the basis of data showing earlier and longer spring flower bloom, allergies and asthma may worsen for individual sufferers or become more widespread through the human population as temperature increases (medium-low confidence). [Chapter 15]
- ***Disadvantaged populations will probably suffer most***. The health of individuals who are elderly, infirm, or economically disadvantaged is expected to decrease disproportionately to that of the general population (high confidence), due to their increased exposure to extreme heat and other climate hazards. [Chapter 15]

Additional effects of climate change

Climate change has the potential to affect many other sectors and populations within the Southwest. For example:

- ***Agriculture will be affected by climate change***. Effects of climate change and associated variability on production of both crops and livestock could be long-lasting, with short-term reductions in profitability (medium-low confidence). [Chapter 11]

- ***Energy supplies will become less reliable as climate changes and climate change will drive increasing energy demand in some areas.*** Delivery of electricity may become more vulnerable to disruption due to extreme heat and drought events that increase demand for home and commercial cooling, reduce thermal power plant efficiency or ability to operate, reduce hydropower production, or reduce or disrupt transmission of energy (medium-high confidence) (Figure 1.10). [Chapter 12]
- ***Climate change will affect urban areas in differing ways depending on their locations and on their response or adaptive capacities.*** Climate change will affect cities in the Southwest in different ways depending on their geographic locations. Local capacity to address effects of climate change will also vary depending on governmental, institutional, and fiscal factors. Incidences of air pollution related to increased heat are likely to increase, and water supplies will become less reliable (medium-high confidence). [Chapter 13]
- ***Reliability of transportation systems will decrease***. Climate change will affect transportation systems in different ways depending on their geographic location (e.g., changing sea level and storm surge affect coastal roads and airports), potentially impeding the movement of passengers and goods (medium-high confidence). [Chapter 14]
- ***Climate change may disproportionately affect human populations along the U.S.-Mexico border***. Climate changes will stress on already severely limited water systems, reducing the reliability of energy infrastructure, agricultural production, food security, and ability to maintain traditional ways of life in the border region (medium-high confidence). [Chapter 16]
- ***Native American lands, people, and culture are likely to be disproportionately affected by climate change.*** Effects of climate change on the lands and people of Southwestern Native nations are likely to be greater than elsewhere because of endangered cultural practices, limited water rights, and social, economic, and political marginalization, all of which are relatively common among indigenous people (high confidence). [Chapter 17]

1.5 Choices for Adjusting to Climate and Climate Change

A century of economic and population growth in the Southwest has already placed pressures on water resources, energy supplies, and ecosystems. Yet the Southwest also has a long legacy of human adaptation to climate variability that has enabled society to live within environmental constraints and to support multiple-use management and conservation across large parts of the region. Governments, for-profit and non-profit organizations, and individuals in the Southwest have already taken a variety of steps to respond to climate change. A wide range of options are available for entities and individuals choosing to reduce greenhouse gas emissions or to prepare and adapt to climate

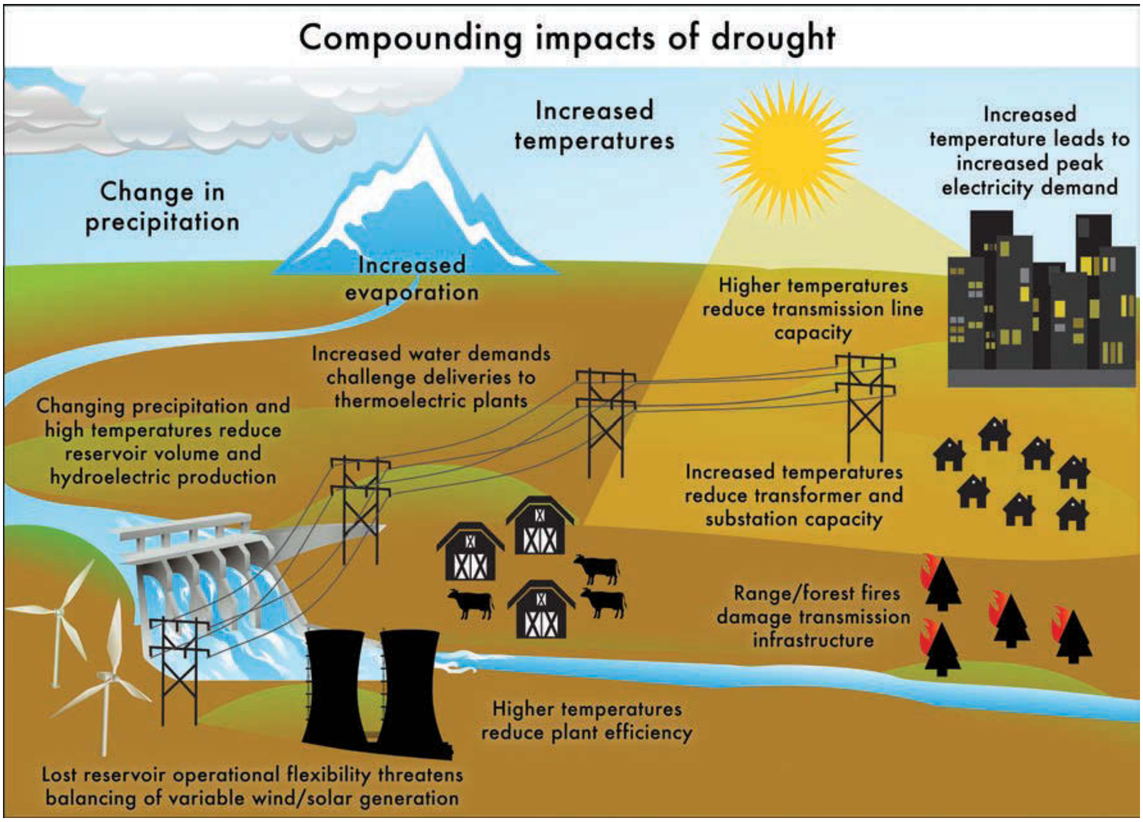

Figure 1.10 Compounding impacts of drought on energy. [Chapter 12]

variability and change (Table 1.2). Others who have not yet begun to respond to climate change directly are choosing to reduce energy and water use for immediate economic benefit or as ways of enhancing the sustainability of water supply, energy, and food production [Chapter 18]. Many options for responding to climate change in the Southwest have been, or are being, investigated, and are assessed in the full report, *Assessment of Climate Change in the Southwest United States.* Notable examples include:

- ***Reducing greenhouse gas emissions***. Governments, for-profit and non-profit organizations, and individuals are already taking many steps to reduce the causes of climate change in the Southwest, and there are lessons to learn from the successes and failures of these early efforts, such as the first U.S. implementation of cap-and-trade legislation in California. There have been few systematic studies, however, that evaluate the effectiveness of the choices made in the Southwest to reduce greenhouse gas emissions (medium-low confidence). California has established targets and the National Research Council has recommended targets for reduction in emissions of greenhouse gases. Meeting these targets will be challenging. However, there are many low-cost or revenue-generating opportunities for emissions reductions in the Southwest, especially those related to energy efficiency and to the development of renewable sources of energy (medium-high confidence). [Chapter 18]

Table 1.2 Adaptation options relevant for the Southwest [Chapter 18]

Sector	Adaptation Strategies
Agriculture	Improved seeds and stock for new and varying climates (and pests, diseases), increase water use efficiency, no-till agriculture for carbon and water conservation, flood management, improved pest and weed management, create cooler livestock environments, adjust stocking densities, insurance, diversify or change production.
Coasts	Plan for sea level rise—infrastructure, planned retreat, natural buffers, land use control. Build resilience to coastal storms—building standards, evacuation plans. Conserve and manage for alterations in coastal ecosystems and fisheries.
Conservation	Information and research to identify risks and vulnerabilities, secure water rights, protect migration corridors and buffer zones, facilitate natural adaptations, manage relocation of species, reduce other stresses (e.g., invasives)
Energy	Increase energy supplies (especially for cooling) through new supplies and efficiency. Use sustainable urban design, including buildings for warmer and variable climate. Reduce water use. Climate-proof or relocate infrastructure.
Fire management	Use improved climate information in planning. Manage urban-wild land interface.
Forestry	Plan for shifts in varieties, altered fire regimes, protection of watersheds and species.
Health and emergencies	Include climate in monitoring and warning systems for air pollution, allergies, heat waves, disease vectors, fires. Improve disaster management. Cooling, insulation for human comfort. Manage landscape to reduce disease vectors (e.g. mosquitos), Public health education and training of professionals.
Transport	Adjust or relocate infrastructure (coastal and flood protection, urban runoff), plan for higher temperatures and extremes.
Urban	Urban redesign and retrofit for shade, energy, and water savings. Adjust infrastructure for extreme events, sea-level rise.
Water management	Enhance supplies through storage, transfers, watershed protection, efficiencies and reuse, incentives or regulation to reduce demand and protect quality, reform or trade water allocations, drought plans, floodplain management. Use climate information and maintain monitoring networks, desalinate. Manage flexibly for new climates not stationarity.

Source: Smith, Horrocks et al. (2011); Smith, Vogel et al. (2011).

- ***Planning and implementing adaptation programs***. There is a wide range of options in most sectors for adapting to climate variability and extreme events, including many that have ecological, economic, or social benefits (medium-high confidence). [Chapter 18]

- ***Lowering or removing barriers to optimize capacity for adaptation***. A number of relatively low-cost and easily implemented options for adapting to climate variability and change are available in the Southwest, including some "no-regrets" options with immediate benefits that could foster economic growth. Lowering or removing financial, institutional, informational, and attitudinal barriers will increase society's ability to prepare for and respond to climate change (medium-high confidence). [Chapter 18]
- ***Connecting adaption and mitigation efforts***. Many options exist to implement both adaptation and mitigation, i.e. options that reduce some of the causes of climate change while also increasing the readiness and resilience of different sectors to reduce the impacts of climate change (high confidence). The significant probability of severe and sustained drought in the drought-prone Southwest makes some adaptation options applicable even in the absence of significant climate change (high confidence). [Chapters 5, 7, 10 and 18]
- ***Planning in coastal areas***. Coastal communities are increasingly interested in and have begun planning for adaptation. There are opportunities to increase use of policy and management tools and to implement adaptive policies (high confidence). [Chapter 9]
- ***Changing water management***. Considerable resources are now being allocated by the water-management sector to understand how to adapt to a changing water cycle. A full range of options involving both supplies and demands are being examined. Large utilities have been more active in assessing such options than relatively small utilities (high confidence). [Chapter 10]
- ***The large amounts of water currently used for irrigated agriculture can buffer urban supplies***. Assuming water allocations to agriculture remain substantial, short-term agricultural-urban water transfers can greatly reduce the total cost of water shortages and limit effects on urban water users during climate- or weather-induced water shortages (medium-high confidence). [Chapter 11]
- ***Changing energy policy***. A shift from the traditional fossil fuel economy to one rich in renewable energy will have substantial effects on water use, land use, air quality, national security, and the economy. The reliability of the energy supply in the Southwest as climate changes depends on how the energy system evolves over this century (medium-high confidence). [Chapter 12]
- ***Adaptation and mitigation on federal and tribal land.*** The Southwest has the highest proportion of federal and tribal land in the nation (Figure 1.11). Native nations are taking action to address climate change by actively seeking additional resources for adaptation, and by initiating climate-change mitigation (medium-low confidence). Federal land and resource management agencies are beginning to plan with the assumption that climate is changing, although efforts are not consistent across agencies (high confidence). [Chapters 17 and 18]

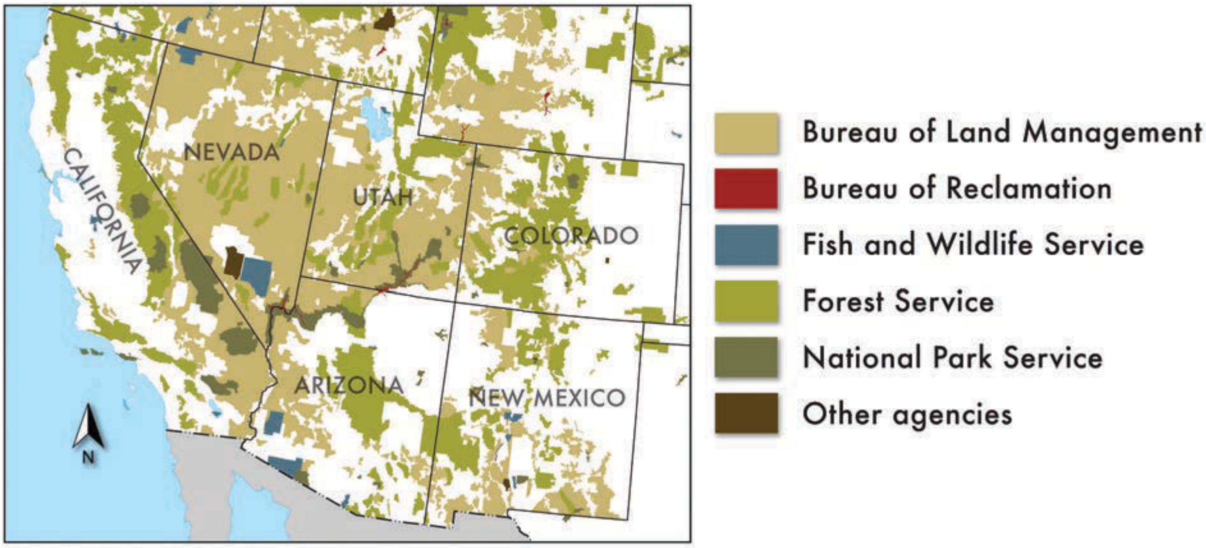

Figure 1.11 Extensive federal lands in the Southwest: A legacy for the future. This map illustrates the legacy of federal land ownership in the Southwest, covering nearly 30 percent of the entire United States. Protected habitat and ecosystem services ensure sustainable management of resources and may be the greatest insurance policy against losses in the future, because natural resource use and biological species can more easily adapt to rapidly changing climatic conditions. Modified from *The National Atlas of the United States of America* (http://www.nationalatlas.gov; see also http://nationalatlas.gov/printable/images/pdf/fedlands/fedlands3.pdf; accessed October 8, 2012). [Chapter 18]

1.6 Key Unknowns

Although there has been a substantial increase in the understanding of how Southwest climate is changing and will change and how this change will affect the human and natural systems of the region, much remains to be learned. The full report, *Assessment of Climate Change in the Southwest United States*, identifies many key unknowns, and assesses the data, monitoring, modeling, and other types of research needed to increase knowledge [Chapters 19 and 20]. Yet, current knowledge and experience is sufficient to support climate change adaptation and mitigation actions, such as reducing greenhouse gas emissions or adapting to the changes that cannot be avoided, minimized, or mitigated. Many of these potential actions represent "no-regrets" options that are already either cost-effective in the immediate or short-term. [Chapter 18]

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Endnotes

i Much of the text in this summary is taken directly, or with minor modification, from the full report, *Assessment of Climate Change in the Southwest United States*, and where this is the case, chapter citations appear in brackets at the end of each paragraph or bullet.

ii Confidence estimates cited in this document (high, medium-high, medium-low, or low) are explained in more detail in the main report. Confidence was assessed by authors of the main report on the basis of the quality of the evidence and the level of agreement among experts with relevant knowledge and experience. [Chapters 2 and 19]