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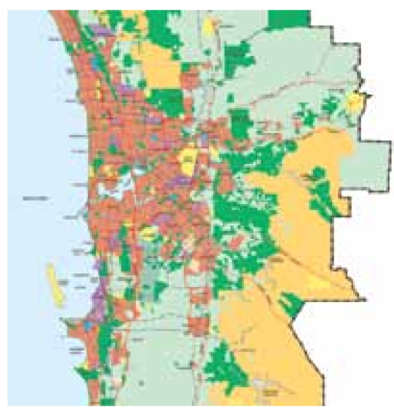
Edited by

Edward J. Blakely
and
Armando Carbonell



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The maps of the United States, Australia, and the nine coastal regions were prepared by Jeremy Weiss, senior research specialist, and Jonathan T. Overpeck, professor, Department of Geosciences, University of Arizona, Tucson. www.geo.arizona.edu/dgesl/

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On each map, the dark blue overlay areas indicate low-lying coastal areas of ≤ one meter elevation vulnerable to future sea-level rise.

Cover images are details of figures and photographs as follows: Top (left to right): figures 1.4, 2.5b, and 3.2; middle: aqueduct, Central Valley, CA (chapter 4), figure 5.3, and Yarra River pollution plume (chapter 6); bottom: figures 7.5, 8.7, and 9.2

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Introduction

Climate Change and Coastal City Regions

Armando Carbonell and Edward J. Blakely

This book reports on responses to climate change in nine coastal cities and metropolitan regions in the United States and Australia. When it comes to climate change, these large, sprawling countries have much in common beyond their predilections for coastal development. First, per capita they are among the highest greenhouse gas (GHG) emitters in the developed world, with Australia usually heading the list and the United States close behind. Second, both countries are exposed to significant climate-related risk relative to sea level rise and storm surge, drought and water shortage, floods, wildfires, and heat waves. The urban regions documented here represent some of the most critical conditions either country faces.

The importance of dealing with potentially severe climate impacts has become increasingly clear. In recent years, we have seen a number of extreme temperature and precipitation events, and climate records were set in countries around the globe. For example, according to the U.S. National Oceanic and Atmospheric Administration (NOAA 2011), in the United States and Australia during 2010 alone:

- The year tied with 2005 as the warmest since record keeping began in 1880. The global combined land- and ocean-surface temperature was 0.62°C (1.12°F) above the twentieth-century average of 13.9°C (57.0°F).
- During the first months of the year, a strong negative Arctic Oscillation—a climate pattern that allows chilly Arctic air to slide south while warmer air moves north—brought snowstorms and record cold to much of the Northern Hemisphere. Polar air reached far into the deep-southern United States in January and February. The record cold weather caused ocean temperatures in the Florida Keys to drop below 15°C (59°F), bleaching and killing coral reefs, which cannot survive sustained cool water temperatures.
- In the Southern Hemisphere, Australia's Bureau of Meteorology reported its warmest summer on record, with an average temperature 0.2°C (0.4°F) higher than the previous record set during the summer of 1997/1998. Australia also experienced its coolest winter in 13 years.

- La Niña brought record rainfall to most of Australia toward the end of the year. The country had its wettest spring on record (from September through November). In contrast to the rest of the country, however, southwestern Western Australia had its driest spring on record.
- In September, following its second-coolest summer on record, the western United States experienced a scorching heat wave during which downtown Los Angeles reached the highest temperature ever recorded there: On September 27, the temperature reached 45ºC (113ºF), breaking the old record of 44.4ºC (112ºF) set on June 26, 1990.

In terms of cost impacts, eight of the ten most expensive presidentially declared disasters in the United States were storm-related (FEMA 2010):

Most Expensive Presidentially-Declared Disasters*

Event	Year	FEMA Funding
Hurricane Katrina (FL,LA,MS,AL)	2005	$29,318,576,948**
9/11 Attack on America (NY, NJ, VA)	2001	$8,818,350,120
Northridge Earthquake (CA)	1994	$6,978,325,877
Hurricane Rita (TX,LA)	2005	$3,749,698,351
Hurricane Ivan (LA,AL,MS,FL,NC,GA,NJ,PA,WV,NY,TN)	2004	$2,431,034,355
Hurricane Georges (AL, FL, MS, PR, VI)	1998	$2,245,157,178
Hurricane Wilma (FL)	2005	$2,110,738,364
Hurricane Charley (FL,SC)	2004	$1,885,466,628
Hurricane Andrew (FL,LA)	1992	$1,813,594,813
Hurricane Frances (FL,NC,PA,OH,NY,GA,SC)	2004	$1,773,440,505

** Numbers are in actual dollars, not adjusted for inflation.*
*** Approximately 68 percent funded.*

Similarly, in Australia the last decade has seen tens of billions of dollars in damage from floods in Brisbane and Victoria, fires in Melbourne and Canberra, and Cyclones Yasi and Larry.

This book deals with both *mitigation* (the reduction of GHG emissions) and *adaptation* (managing the climate-impact risks that cannot be avoided), as the terms are generally used in this field. Stern (2007, 24) has laid out the mitigation dilemma:

> Much economic activity involves the emission of GHGs. As GHGs accumulate in the atmosphere, temperatures increase, and the climatic changes that result impose costs (and some benefits) on society. However, the full costs of GHG emissions, in terms of climate change, are not immediately—indeed they are unlikely ever to be—borne by the emitter, so they face little or no economic incentive to reduce emis-

> sions. Similarly, emitters do not have to compensate those who lose out because of climate change. [Symmetrically, those who benefit from climate change do not have to reward emitters.] In this sense, human-induced climate change is an externality, one that is not "corrected" through any institution or market [Pigou 1912], unless policy intervenes.

The Lincoln Institute of Land Policy initially became involved in the issue of climate change through our work with planning directors in the 30 largest cities of the United States. As early as 2006 these city planners were raising a new question: How do we respond when our mayors ask about global warming?

In 2005 as the Kyoto Protocol was going into effect—before Nicholas Stern (2007, i), in his important review, declared climate change the "greatest and widest-ranging market failure ever seen," or the fourth report of the Intergovernmental Panel on Climate Change (IPCC 2007) laid out in stark terms the consequences of inaction—many big-city mayors had joined with those from more than 1,000 other municipalities in signing the U.S. Conference of Mayors Climate Protection Agreement, launched by Seattle Mayor Greg Nickels. Other mayors had joined the pioneering ICLEI (now Local Governments for Sustainability) Cities for Climate Protection. Still others were working with either the Clinton Climate Initiative or the C40 Cities Climate Leadership Group, two efforts to help large cities reduce their greenhouse gas (GHG) emissions that since have merged. The planning directors' queries led to a series of briefings in Cambridge, Massachusetts, at a 2007 seminar that was part of an annual program convened by the Lincoln Institute in collaboration with the American Planning Association and the Graduate School of Design at Harvard University.

Around the same time, the Lincoln Institute commissioned longtime colleague Edward J. Blakely to write a working paper on the topic of urban planning for climate change (Blakely 2007), shortly before he was called to New Orleans to head the city's post–Hurricane Katrina recovery effort. Working with other North American colleagues, the Institute also published two policy focus reports on related topics: *Urban Planning Tools for Climate Change Mitigation* (Condon, Cavens, and Miller 2009) and *Planning for Climate Change in the West* (Carter and Culp 2010).

The present volume has benefited from Ed's experiences in the trenches in New Orleans, Australia, and elsewhere, Armando's seminars on climate change and cities, and the studio on Climate Change, Water, Land Development, and Adaptation that he taught at the Harvard Graduate School of Design, with sponsorship support from the Dutch government. But above all, this book is the work of the contributing authors from the United States and Australia, who diligently prepared their chapters, brought them to Cambridge to be critiqued in a seminar in 2010, and provided revisions and updates throughout the copyediting and book design process. Some of the U.S. authors also traveled to Perth in Western Australia to meet with Ed Blakely and several of the Australian authors to present our findings at the World Planners Congress in July 2011.

At least from the vantage point of the United States, it appears that the pendulum has swung from an initial emphasis on mitigation, as reflected in the mayors' initiatives in response to the Kyoto Protocol, to one focusing on adaptation, as cities begin to prepare for the onslaught of climate-related impacts. The nine cases presented in the following chapters show a range of adaptation responses. As we will consider in the concluding chapter, however, in order to avoid catastrophic results it remains necessary to reduce GHG emissions significantly. While there are encouraging developments at the national level in Australia, recent analysis suggests that the time for action is critically short. It remains to be seen whether governments will rise to meet the global challenge.

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Resilient Coastal City Regions

United States of America

Source: Weiss and Overpeck, University of Arizona

dark blue overlay areas = low-lying coastal areas of ≤ one meter elevation vulnerable to future sea-level rise


QUEBEC
NEW BRUNSWICK
Quebec
MINNESOTA
Ottawa
Montreal
MAINE
Saint John
Minneapolis
WISCONSIN
MICHIGAN
Toronto
NEW YORK
Portland
Milwaukee
Boston
Detroit
Buffalo
IOWA
Des Moines
Chicago
Cleveland
MASSACHUSETTS
OHIO
PENNSYLVANIA
ILLINOIS
New York
Kansas City
Indianapolis
Springfield
Columbus
Philadelphia
INDIANA
Baltimore
St Louis
Louisville
Charleston
KENTUCKY
VIRGINIA
Virginia Beach
MISSOURI
TENNESSEE
Little Rock
Memphis
Charlotte
NORTH CAROLINA
ARKANSAS
Birmingham
Atlanta
Columbia
SOUTH CAROLINA
Jackson
GEORGIA
ALABAMA
LOUISIANA
New Orleans
Jacksonville
FLORIDA
Miami
Naussau
Gulf of Mexico
Havana
Bahamas

Figure 1.1 **New York City**

Source: Weiss and Overpeck, University of Arizona.

dark blue overlay areas = low-lying coastal areas of ≤ one meter elevation vulnerable to future sea-level rise

Chapter 1

New York City

Robert D. Yaro and David M. Kooris

The New York metropolitan region is especially susceptible to adverse effects of natural disasters due to its geographic location on an archipelago and adjoining peninsulas of the United States mainland (figure 1.1). The area's densest urban communities, including Manhattan Island and adjacent areas of Long Island and Staten Island, are close to New York Harbor, the Hudson River Estuary, and Long Island Sound. Much of the development in these areas has been built on low-lying land prone to tidal and storm-related coastal flooding that is exacerbated by sea level rise.

Despite its location in a temperate climate zone, the New York City region is also prone to extreme summer heat waves, compounded by the urban heat island effect. During these increasingly frequent events, daytime temperatures can exceed 100ºF, threatening public health. The city has taken actions to develop detailed projections of the impacts of such climate-related changes, yet only recently with a focus on adaptation policy. Fragmented governance may further hinder the ability to protect this productive region. A better understanding of this sensitive ecosystem and new policy mechanisms is required to deal effectively with these and other climatic conditions.

Geological, Cultural, and Land Use History

About 20,000 years ago, the Wisconsin Glacier began its steady retreat northward from present-day New York City, freeing the region from the ice blanket that had covered it for millennia. At its southernmost maximum extent, the massive glacier had deposited a terminal moraine nearly 100 miles long (figure 1.2). This ridge trapped a meltwater lake behind its sandy and rocky dam. Toward the western edge of this linear mound, an outcrop of ancient bedrock that had been exposed by the friction of the glacier stood high in this low-lying landscape. A wide river delivering ancient water from the highlands meandered west around the moraine before eventually meeting the constantly rising Atlantic Ocean.

Over the next 15,000 years, the contrasting forces of south-moving freshwater and northward pressure from the ocean formed a series of new channels that carved the terminal moraine into a series of smaller islands. The meltwater lake broke through the moraine to form Long Island Sound, framed at its eastern end by the channel known as the Race and to the west by the East

Figure 1.2 Geology of the Tri-State Metropolitan Region
Source: Regional Plan Association.

River. The force of the Hudson River bringing freshwater south from the highlands eventually created the most direct path. It punched through the terminal moraine between Staten Island and Long Island, and joined what are now the upper and lower bays of New York Harbor. Over the millennia, as the changing climate combined with hydrologic forces, an archipelago off the northeast coast of North America offered the ingredients to support human civilization.

About 3,000 years ago, several waves of Native American tribes moved into the region and made a permanent settlement. By the time European ships set sail for the New World, approximately 5,000 members of the Lenape tribe lived within the current city limits of New York, and several thousand members of other tribes congregated in the surrounding region. As sixteenth- and seventeenth-century European explorers charted the region and set up trading posts, the strategic value of this protected harbor's location became clear, and the cultural foundations of an open society evolved in the then-Dutch colony (Hornberger 2005).

By the late seventeenth century, wars and disease brought on by European colonization had decimated the Native American population and left the region under British control. In the eighteenth century, the thriving trading post evolved into a city that was an important battle site during the Revolutionary War and ultimately the political epicenter of the new Republic. Though the city ceased to be the new nation's capital, the construction of the Erie Canal and immigration in the nineteenth century ensured that it would become the fledgling country's economic center. Over the last 100 years, significant infrastructure investments and governance decisions have propelled New York City's evolution into the global metropolitan region it is today (Burrows and Wallace 2000).

Metropolitan New York stretches far beyond the city's borders. A transportation system that includes hundreds of miles of highway and nearly 1,000 fixed-route transit stations connects employment and housing centers across three states, 31 counties, and more than 700 municipalities. The region is currently home to approximately 23 million people and more than 10 million jobs. Annually, the economic activity produced in this most vibrant subset of the United States economy totals $1.2 trillion.

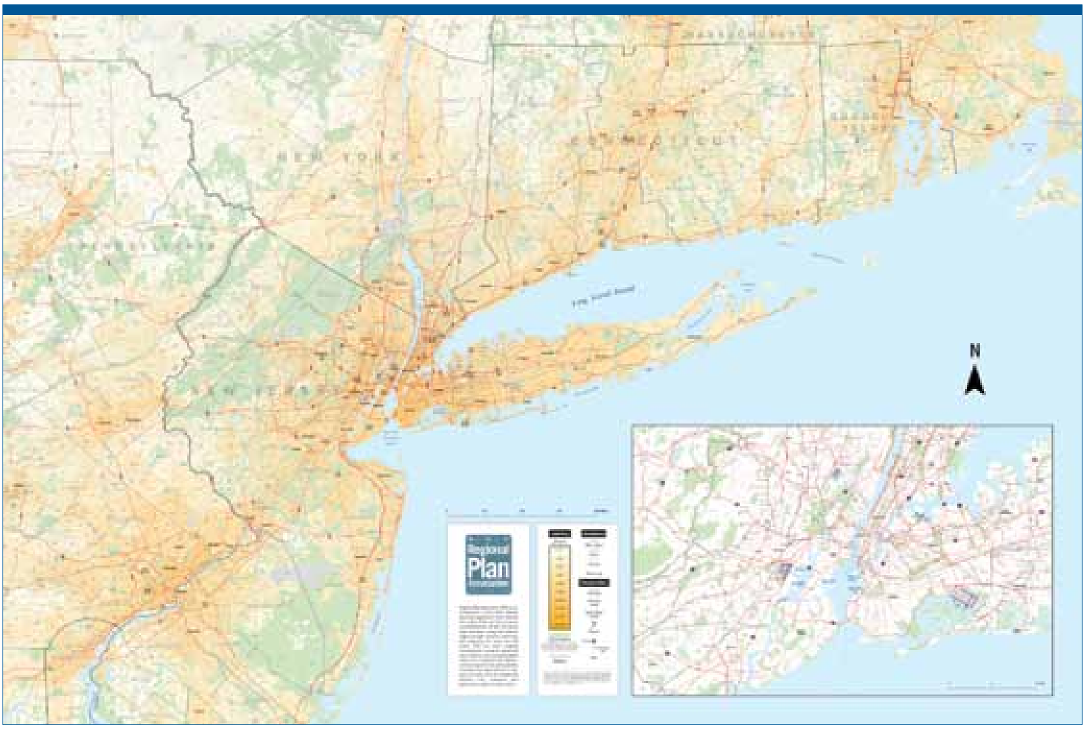
Much of the last half-century's growth has centered around highways rather than the rail network (figure 1.3). Decades of sprawl have resulted in automobile-dependent suburban and exurban communities that are incredibly energy intensive and have few public open spaces. Although its urban core is the most densely populated urban area in the United States, the successive rings of lower density development have given Metropolitan New York an average density less than that of Metropolitan Los Angeles, a region often considered the epitome of urban sprawl (Fulton et al. 2001).

Its high densities and intensive transit use give New York City among the lowest greenhouse gas (GHG) emissions per capita of any municipality in the country. Many surrounding suburban communities have higher per capita emissions rates that tend to accompany higher-income residential areas, even though they tend to be transit-friendly and relatively compact. Coordinated land use and transportation policies, efficient building retrofits, renewable power generation, and landscape preservation for carbon sequestration are needed to make this region sustainable, mitigate the most severe impacts of climate change, and adapt to those impacts that are already unavoidable.

Impacts of Climate Change on the Region

As the science concerning climate change is researched and documented and local modeling is conducted, the implications of global temperature rise on local weather patterns and ecological conditions in Greater New York are

Figure 1.3 Residential Densities and Infrastructure in the Tri-State Region
Source: Regional Plan Association.



becoming better understood. The Union of Concerned Scientists has modeled the impacts on a subnational scale providing a clear picture of the anticipated effects of climate change on the northeastern United States (Frumhoff et al. 2007). This analysis was augmented by the New York City Panel on Climate Change (NPCC) using modeling techniques that provide a more refined level of detail for this metropolitan area (Horton et al. 2009).

The expected impacts on the communities that make up Greater New York can be defined broadly within three categories: sea level rise and storm surge, rain and storms, and heat waves (table 1.1). The impacts described in the following sections are based on the probability of temperature increases in the region. While different models applied at different scales predict a range of climate outcomes toward the end of the twenty-first century, their projections through mid-century are fairly consistent. Summer temperature increases between 1.5ºF and 3.5ºF can be expected between now and 2030, with increases of between 4 and 8ºF by mid-century. While this might seem harmless, especially on a cold winter day, the impacts can be quite severe and can be exacerbated during extreme weather events.

Table 1.1 Climate Impacts on the New York Metropolitan Region
Sources: Frumhoff et al. (2007); Horton et al. (2009).

	Baseline		Early Century					Mid-Century					Late Century				
	NPCC (1971–2000)	North-east	NPCC	Northeast				NPCC	Northeast				NPCC	Northeast			
				Summer		Winter			Summer		Winter			Summer		Winter	
				Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
Sea level rise (in.)	N/A	relative to 2005	2–5	0.5–1				7–12	4–5				12–23	9.6–16.1			
Sea level rise rapid approx. (in.)	N/A	relative to 2005	5–10					19–29					41–55				
Precipitation (in.)	46.5	?	0.5%	little change		?	?	0–10%	little change		?	?	5–10%	little change		20%	30%
Air temperature (°F)	55	?	1.5-3	1.5–3	1.5–3.5	2.5–4	2.5–4	3–5	2–5	4–8	4–5	4–7	4–7.5	3–7	6–14	5–8	8–12
Days above 90°F	14	15	23–29	23	26	N/A	N/A	29–45	36	51	N/A	N/A	37–64	41	79	N/A	N/A
Days above 100°F	0.4	2	0.6–1	N/A	N/A	N/A	N/A	1–4	N/A	N/A	N/A	N/A	2–9	8	28	N/A	N/A

Sea Level Rise

The most widely known effect of global warming is the impact of melting glaciers on sea level as once-landlocked ice enters the oceans. New York City encompasses close to 600 miles of coastline, and the region adds another 2,200 shoreline miles, making the metropolitan area particularly susceptible to sea level rise. Several analyses of projected sea level rise have been conducted by the Union of Concerned Scientists, the Earth Institute at Columbia University, and the NPCC. The projections from the latter two studies are based on more locally specific data and modeling. Each instance presents a potential range of sea level rise dependent on GHG emissions and many other factors related to the melting rate of the world's glaciers.

The NPCC projects minimum sea level rises of 2 inches by 2020, 7 inches by 2050, and 12 inches by 2080 (Horton et al. 2009). For the same three target years, the Earth Institute's projected rises are 4.3, 6.9, and 9.5 inches, respectively (Rosenzweig and Solecki 2001). Given the uncertainty over the long term, it is important to note that, despite the varying rates of rise at this low end of the projection range, both sources point to an approximate minimum sea level rise by mid-century within the metropolitan region of 7 inches. At the high end, while they become increasingly divergent, all the projections are threatening.

If climate change factors compound to increase the rate of glacial melt, the NPCC projects sea level rise of 5 inches by 2020, 12 inches by 2050, and 23 inches by 2080 (Horton et al. 2009). The Earth Institute's compilations suggest even greater increases of 11.7, 23.7, and 42.5 inches, respectively (Rosenzweig and Solecki 2001). Based on these forecasts, New York's metropolitan coastline is likely to experience at least one foot of sea level rise within the lifetime of the region's current elementary school students.

Recent observations near the North and South Poles and the characteristics of the coastal northeastern United States indicate that these projections may be too optimistic. Current rates of melting are much closer to the average rates that occurred during the last glacial retreat than the lower rates projected in the current climate models. It has been observed that the polar regions are more sensitive than the mid-latitudes to climate change and will, therefore, demonstrate impacts more rapidly than other parts of the globe. For these reasons, combined with uncertainty in the Intergovernmental Panel on Climate Change (IPCC) models, the NPCC decided to explore a "rapid ice melt sea level rise scenario," which projected sea level rise late in this century at between 41 and 55 inches (Horton et al. 2009). This is closer to the Earth Institute projection of 42.5 inches and points to a significantly higher impact on the coastal metropolitan area.

These projections may be conservative, and each additional inch of ocean level will have its own impact on various coastlines around the globe. Recent studies show that the northeastern United States will be disproportionately affected by rising seas. According to an analysis published in *Nature Geoscience*, dynamic sea level rise along the northeastern seaboard will occur almost twice as fast as in the world as a whole (Yin, Schlesinger, and Stouffer 2009). This drastic sea level rise differs from coast to coast mainly because of the cessation of deep convection and deepwater formation in the Labrador Sea and the slowdown of the subpolar gyre.

The combination of larger sea level rises and more concentrated populations relative to other coasts means the Northeast is among the U.S. regions most vulnerable to climate change. Though projections encompass a significant range, recent observations at the poles support the hypothesis that increased sea level rise will occur in the New York metropolitan area and indicate that, in the coming decades and certainly by the later years of this century, it will be an inevitable aspect of life in this region, making adaptation essential.

Coastal Storm Surge

Future coastal storms and the surges they create as they approach land will significantly compound the risks of sea level rise in the region. New York City has a long history of hurricanes and nor'easters. Climate change makes it nearly inevitable that more severe challenges involving these natural events are yet to come. The city's location makes it particularly vulnerable to storm surges from massive coastal storms because the nearly right-angle intersection of the coast of New Jersey with Long Island acts as a funnel and pushes high waters into New York Harbor. Urbanization has cost the region 85 percent of its coastal wetlands, further reducing the natural capacity of the landscape to buffer developed areas from the impact of storms.

In the early nineteenth century, a Category 4 hurricane that made landfall at Jamaica Bay one September caused a 13-foot storm surge that hit Lower Manhattan and led to flooding as far north as Canal Street. Historically, this was considered a very rare occurrence because ocean temperatures in the Northeast in the fall are normally cool. Later that century, however, a far weaker Category 1 or 2 storm completely obliterated Hog Island in Jamaica Bay, where summer cottages and fishing posts had been built. The enormous Long Island Express Hurricane of 1938 hit the shores of eastern Long Island and Connecticut with a 25- to 30-foot wall of water, killing 700, injuring thousands, and causing billions of dollars in property damage.

In the second half of the twentieth century, a Category 3 hurricane in 1960 and a massive nor'easter in 1992 each flooded parts of Lower Manhattan and at the Battery posted rises above mean sea level of 8.5 and 7.7 feet, respectively. The 1992 storm caused seawaters to flood coastlines across the region and to overtop some entrances to the PATH rapid transit system, resulting in serious damage and causing hundreds of millions of dollars in damage to housing, utilities, and commercial development. A storm surge as little as another foot or two higher—equivalent to the increases anticipated due to sea level rise in the coming half-century—would result in still more widespread flooding. Even without the effect of sea level rise or the full impacts of climate change, the city's infrastructure has been taxed by recent heavy coastal storms. Just during the past decade, New York City subways have experienced flooding three times, and each time large portions of the region's mobility system were shut down (Center for Climate Systems Research n.d.; Gornitz 2001; Gornitz et al. 2006; and Jacob 2001).

In the mid-1990s, the U.S. Army Corps of Engineers specifically considered the impact that storm surges associated with hurricanes of different magnitudes would have on the city's transportation infrastructure. If a Category 3 hurricane were to take a path up the east coast toward New York City at the most severe angle, it could create a surge of up to 25 feet at John F. Kennedy International Airport, 21 feet at the Lincoln Tunnel, 24 feet at the Battery in Lower Manhattan, and 16 feet at LaGuardia Airport. Both the Lincoln and Holland Tunnels would be completely inundated (U.S. Army Corps of Engineers 1995). As staggering as these results are, the modeling does not include the potential additional effect of a high tide or the height of waves on top of the surge.

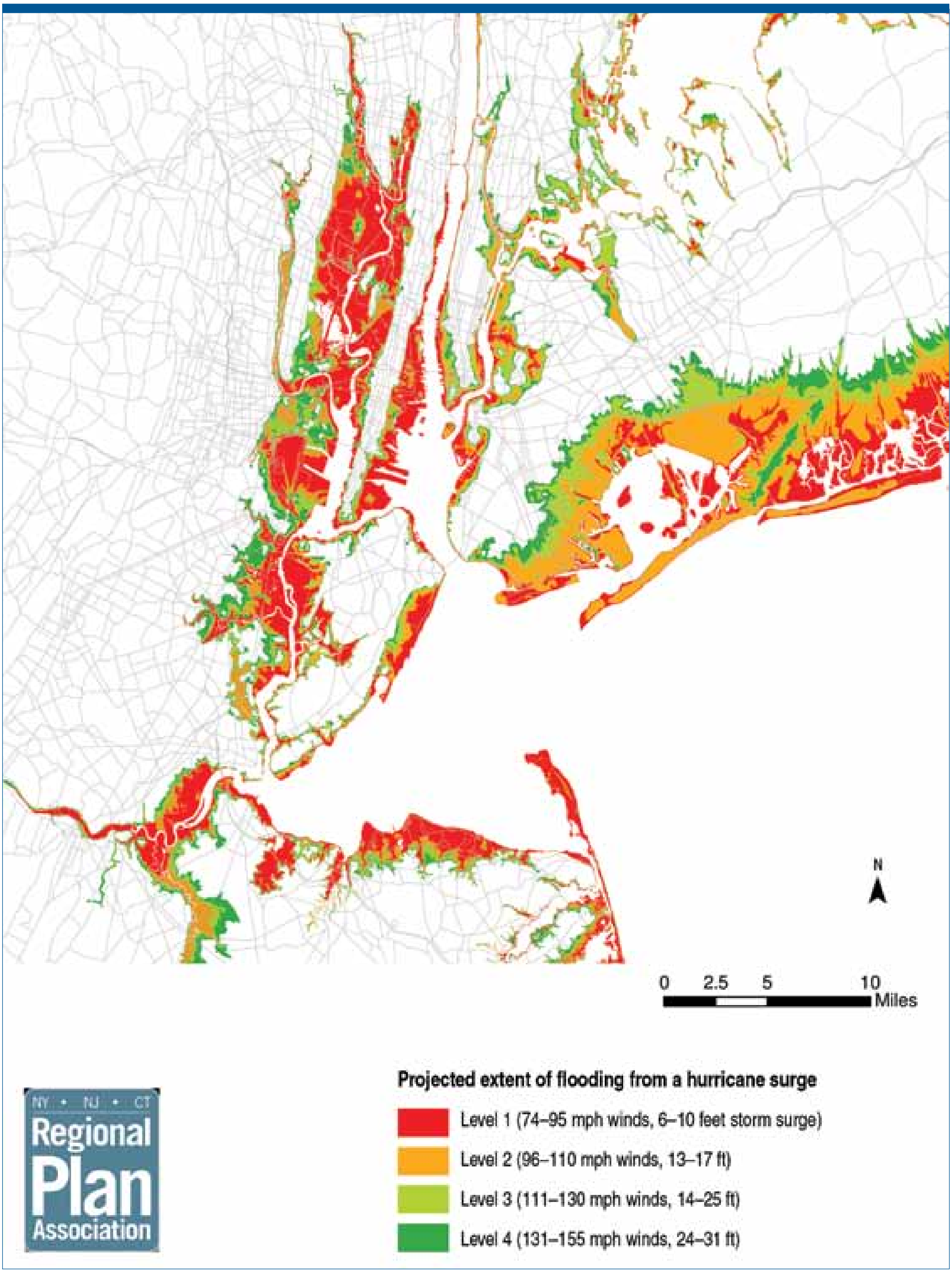
Subway flooding in New York during a 1992 Nor'easter
Photograph: Courtesy of US Army Corps of Engineers, NY District

Although Category 4 storms have been rare, ocean waters are projected to become significantly warmer, thus increasing potential storm frequency. The Army Corps' analysis identified surges associated with such a storm reaching 31 feet at Kennedy Airport and the Lincoln Tunnel, 29 feet at the Battery, and 21 feet at LaGuardia Airport. Compounded by sea level rise, the result could be catastrophic. In addition to the impact on critical infrastructure, the destruction of property would be immense because so much of the coastline supports homes and offices of increasing value (figure 1.4). If a storm in 2011 followed the same path as the Long Island Express hurricane, projected losses would total $39.2 billion (2005 dollars) across the Northeast (Pielke et al. 2008).

Rainfall: Frequency and Intensity

Lack of rain and desertification are likely results of climate change in many regions of the globe, but Greater New York is expected to experience more rainfall than in the past, as predicted by the Northeast Climate Impacts Assessment (Frumhoff et al. 2007). While the models do not demonstrate clear consensus, and it is difficult to project changes in average annual rainfall, the metropolitan area could see increases of up to 10 percent within the next few decades (Horton et al. 2009). Declines may be observed during certain seasons,

Figure 1.4 Vulnerability to Hurricane Flooding in the New York City Region
Source: Regional Plan Association.



but the increases are most likely to occur in the winter months. This changing distribution over the course of the year has an impact on both water supplies and drought. Significantly more important than the increased amount of rain and its annual distribution, however, is the trend toward increasingly frequent extreme storms. The intensity of these storms, the amount of rain deposited in a short time period, and the accompanying winds and surges could be the catastrophic hallmarks of climate change throughout the region.

Inland and along the coast, these storms can overwhelm the capacity of natural drainage systems. Even though the amount of forestland in the Northeast is at its highest acreage since the rise of European settlement, the amount of impervious surface has also increased dramatically. Exurban and suburban development has converted forestland and grassland into building footprints, roadways, and parking lots, significantly impairing the ability of many natural watersheds to manage downpours. Rain that should otherwise be held in the tree canopy or slowly percolate into the ground instead is channeled into pipes and rapidly dumped into streams and rivers. The impacts of such rainfall are likely to include flooding and contamination of waterways and water supplies in many communities.

The greater probability of intense storm events increases the likelihood that more severe flooding will occur, which in turn will force communities to rethink development location based on the amount of risk they are willing to accept. While little construction has occurred on designated 100- and 500-year floodplains since flood-risk mapping came into use, much of the region's existing development is located close to rivers' mouths. Contemporary forecasts conclude that within 10 years, 100-year floods could begin to occur as often as every 43 years, which would double the risk facing development located in the region's vulnerable areas. By 2050 a so-called 100-year storm could occur as often as every 19 years and that could ratchet up to as often as every 4 years by 2080.

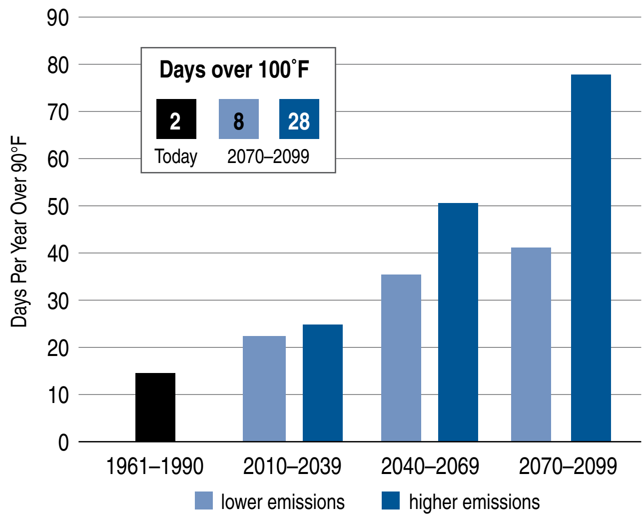
Flooding currently viewed as an anomaly may soon occur once or twice a decade, and that will completely alter insurance risks and threaten the value of significant portions of the metropolitan region. As more intense rainstorms hit the hard surfaces covering so much of the area, run-off will accelerate, threatening both more frequent and more severe flooding as well as increasing the extent of pollutants entering the waterways. Of greatest importance is the increased risk of contaminants entering the unfiltered reservoirs of New York City in the valleys of the Hudson and Delaware Rivers. Contamination in these reservoirs will put the region's potable water supply at risk, requiring significant investment in filtration infrastructure to secure the integrity of this crucial resource (Demong et al. 2008).

Heat Waves

Severe storms stem from the rising temperatures associated with global warming. Overall, under a low emissions scenario, the climate of the tri-state area in 2050 is anticipated to be like that of coastal Virginia in 2010 or, if emissions continue to rise at current rates, it will be more like coastal South Carolina or Georgia (figure 1.5). While rain is projected to increase on the whole, and intense storms will become more frequent, summers will be even hotter. Extreme heat and rainfall variability and intensity will lead to extended heat waves and drought. Currently, the region experiences an annual average of 14 days that reach temperatures greater than 90°F. By 2020, this number is likely to increase to between 24 and 40 days. By mid-century between 30 and 62 days per year will exceed the mark, which is equivalent to between one and two months of heat waves. In 2080, the number could reach a staggering 89 days annually—fully one-quarter of the year.

Figure 1.5 Impact of Global Warming on Heat Waves in Central Connecticut

Source: Frumhoff et al. (2007).



These heat waves will be accompanied by more frequent and severe droughts. Higher temperatures could result in reducing snowpack, which feeds a portion of the region's water supply. As supply is constrained, increased heat will also lead to increased demand for water. Compounded by the potential reduction in reservoir volume stemming from the lack of rainwater recharge, significant conflicts could arise between the needs to maintain maximum reservoir levels and to keep storage capacity that helps mitigate increased flooding risk throughout the watershed (Demong et al. 2008).

City and State Planning for Climate Change

The implications of these data demonstrate the need to adapt to a changing climate, and planning for its threats has begun at multiple levels of government. In the face of federal inaction on this issue, municipal measures to address climate change have received significant national and global attention. Many of these local plans have been supported strongly by the business community, increasing the likelihood of their success. However, up to now most municipal plans have focused almost exclusively on mitigation instead of climate adaptation.

New York City

New York City is taking a leadership role in addressing both adaptation and mitigation in its planning efforts. The scale of its watersheds and water distribution system ensures that the Department of Environmental Protection is concerned with a geography significantly larger than the city's 300 square miles, an area already much larger than that of the average municipality in the region. Although the Office of Long Term Planning and Sustainability and the Department of City Planning have recently taken the lead in a robust approach to adaptation planning, the city's initial climate action efforts focused on mitigation planning.

In 2007 New York City's Mayor Michael Bloomberg led the creation of PlaNYC 2030, a comprehensive sustainability and climate plan with detailed recommendations. It included land use recommendations to accommodate an additional one million residents in transit-oriented locations; open space and water quality recommendations to provide every resident with access to parkland and waterfront; recommendations to reduce demand for electricity through building efficiency and green supply using renewable options; and transportation recommendations to increase the city's already high transit trip share. The plan also laid out detailed performance measures to track progress in achieving these goals, and by 2009 most of the short-term objectives had been reached. The city is now in the process of revising PlaNYC in accordance with a new local law that requires plan updates every five years.

PlaNYC contains three specific recommendations related to adaptation: (1) create an intergovernmental task force to protect vital infrastructure; (2) work with vulnerable neighborhoods to prepare site-specific plans; and (3) launch a citywide strategic planning process for adaptation. To achieve the first goal, in 2008 the mayor convened the NPCC to determine the likely impacts of global warming on the city by compiling existing analyses and conducting modeling exercises. The panel further determined what adaptation responses will be used to address those impacts that cannot be avoided through mitigation strategies already adopted in PlaNYC. The panel is using these more location-specific projections to identify risks posed to critical infrastructure and propose strategies for adaptation.

In spring 2008, the city began a partnership with Brooklyn's United Puerto Rican Organization of Sunset Park (UPROSE) to conduct pilot workshops in that neighborhood as a first step toward achieving its second goal of developing a citywide strategy for local plans in vulnerable areas. Later that year the effort was expanded to include pilot workshops in all five boroughs, and the full outreach and development strategy is now being finalized. To attain the third goal, the city will be starting a strategic planning process for adaptation as a component of a sustainable communities regional planning grant through the U.S. Department of Housing and Urban Development (HUD).

New York State

In areas of the state outside New York City, adaptation planning is taking place at the state agency and subregional levels. The Office of Climate Change, part of the state's Department of Environmental Conservation (DEC), established the Climate Smart Communities program, which offers resources on mitigation and adaptation for municipalities. The DEC also chairs the legislatively established Sea Level Rise Task Force, which released its report on 31 December 2010. Of the state's 62 counties, 17 lie in the coastal zones of the Atlantic Ocean, Long Island Sound, and the tidal portion of the Hudson River.

The task force's report assesses impacts and potential strategies put forth to protect the state's coastal ecosystem, public works and infrastructure, and local communities. The focus is on nonstructural strategies aiming to enable the natural systems to adapt to sea level rise while new development avoids vulnerable areas, retreats from them, or enables migration of natural protection mechanisms. Between 2004 and 2009, New York State spent nearly $23 million on projects to protect public infrastructure and private property from erosion and coastal area flooding. Several hundred million dollars more are to be used for projects on Long Island alone.

Because sea level rise will make constant replenishment of beaches and dunes impossible, the report focuses on enabling these geological features to migrate inland. This strategy is not feasible in the urban core, however, and the report's significant reliance on nonstructural solutions resulted in New York City withholding support for five of the thirteen recommendations. The report does acknowledge that, while nonstructural strategies are preferred, adaptation will "require a multitude of flexible, non-exclusive, location-specific approaches" (Sea Level Rise Task Force 2010, 54). With more than $125 billion in residential assets alone within the 100-year floodplains of Nassau, Suffolk, and Westchester Counties and New York City, specific interventions need to be found.

The report's 13 recommendations deal with policies, partnerships, funding, research, and outreach. The first of them sets the stage for future action by proposing that the state officially adopt the sea level rise projections of the task force through a legislative act or executive order. This will put all agencies and government entities on the same page regarding assessment of the threat facing New York. Several recommendations, however, focus on the necessary, but still unfunded and incomplete, research required to determine the nature of more specific and local impacts in order to make response actionable at multiple levels of government. While some recommendations call for amending policy and eliminating current subsidies that can serve to increase community resiliency at little or no cost, many aspects of the plan will require funding. The recommendations include several innovative funding mechanisms, such as dedicating real estate transfer taxes on sales of luxury housing within the coastal zone for adaptation actions, and exchanging publicly owned properties acquired as a result of tax delinquency with homeowners whose houses occupy land in vulnerable areas. The report highlights the realities that there are no easy solutions, a broad range of strategies will be necessary, and protection of the most concentrated and valuable aspects of the built environment entails more research and inventive responses for the urbanized core of the region.

In coordination with several university partners, the New York State Energy and Research Development Authority (NYSERDA) has funded ClimAID, a statewide climate adaptation assessment (New York State ClimAID 2009). In the coming years the initiative will focus on case studies to demonstrate the interconnectedness of climate impacts and adaptation strategies with co-benefits to communities to address multiple threats simultaneously. In 2011, NYSERDA began this process by issuing a request for proposals for regional coordinating organizations or consultants to help communities on Long Island, in the Hudson Valley, in the Albany capital region, and upstate municipalities complete regional GHG inventories; develop action plans; and align local, regional, and state policy to achieve reduction targets.

While Long Island is just beginning a comprehensive sustainability planning process that will include adaptation recommendations, the Hudson Valley is the subregion of the metropolitan area farthest along in preparing its climate adaptation strategy. Rising Waters is a collaborative effort of the Eastern New York Chapter of The Nature Conservancy and its partners: the Hudson River Estuary Program of the DEC, Hudson River National Estuarine Research Reserve, Cary Institute of Ecosystem Studies, New York State Water Resources Institute at Cornell University, and Sustainable Hudson Valley (Nature Conservancy 2009). During 2008 and 2009, the effort brought together more than 150 local representatives in a series of scenario planning workshops to explore the implications of climate change and possible adaptation courses. Over the coming years, working groups will advance policies that aim to improve community preparedness for extreme events, incorporate climate impacts into the land use planning process, guide future development away from floodplains, and make critical infrastructure more resilient. Rising Waters uses a model process to engage a wide range of stakeholders and identify those strategies that provide the greatest benefit given the range of impacts the region will likely face in the future.

Rising Waters began with the development of four scenarios that consider how Hudson Valley communities and agencies might deal with the impending impacts of climate change up to 2030.

1. Procrastination Blues assumes very little action within the time period.
2. Stagflation Rules demonstrates economic stress that may result only in land regulatory adaptation measures.
3. Nature Be Damned depicts a future where large engineered megaprojects are built in response to damaging floods.
4. Give Rivers Room outlines a future in which flooding continues even after megaproject construction and a new push toward nature-based solutions are in place. (Aldrich, Dunkle, and Newcomb 2009)

Eighty climate response actions were measured against eight criteria in order to assess ease of implementation, ability to achieve desired adaptation goals, ability to limit negative social and environmental externalities, and potential to be transformative. Each of the responses was assessed within the context of the four scenarios and ranked on its ability to respond correctly in a variety of contexts. The five most effective actions were: (1) holding regular neighborhood meetings to discuss response; (2) updating community-based emergency response plans coordinated with state agencies; (3) requiring local communities to work with the state's Office of Emergency Management to maintain updated regional hazard and predisaster mitigation plans; (4) requiring state agencies to conduct flood-risk assessments of all major infrastructure; and (5) changing the requirements for stormwater permits.

Connecticut

In 2009 the State of Connecticut's Department of Environmental Protection began assessing adaptation options and released a series of eight reports (based on the NPCC modeling) detailing the effects of climate change in sectors related to human habitation and environmental quality. The reports examined biodiversity and habitat, fisheries, forestry, infrastructure, natural coastal shoreline environment, outdoor recreation, water resources, and wildlife.

Four working groups were established to study the impacts and adaptation strategies addressing the state's agriculture, infrastructure, natural resources and ecological habitats, and public health needs. Their initial reports summarized the threats to these four sectors and were released in early 2010. The groups presented draft adaptation strategies and implementation plans to the state legislature in mid-2010 (Connecticut Department of Environmental Protection 2009). The following discussion outlines some of those findings for each sector.

Though one may not think of agriculture as a significant part of the economy in an urbanized northeastern state, Connecticut's nearly 5,000 farms comprise more than 13 percent of its land area and produce goods that exceeded $550 million in sales in 2007. Of greatest significance are its oyster crop (highest value in the nation); milk production (highest yield per cow of any location east of Michigan); witch hazel (highest production in the nation); and black currants (highest production in North America). Dairying in particular will be significantly impacted by the heat and storm effects on herds. The increase in temperature will require additional cooling operations to prevent the spread of infectious disease among cattle and keep dairy cows cool to reduce stress. Warm waters will improve shellfish growth off the Connecticut coast, but may increase their susceptibility to disease.

Two of the state's most successful crops—witch hazel and grapes—will benefit from warmer weather and a lengthened growing season, and these conditions will also raise the possibility of biofuel production in areas where it is currently not supportable. On the other hand, maple syrup production may be impossible by 2080 due to the disappearance of a freeze/thaw cycle. Increased temperatures and precipitation will also place warm-weather crops at significant risk during the second half of the summer, making them more susceptible to pathogens and bacteria. Many such crops depend on consistent temperatures and precipitation to thrive.

Enabling an urban, suburban, and rural population to prosper in Connecticut has required significant investment in the built environment and infrastructure involved in transportation, energy, water, wastewater, stormwater, and coastal protection. Models developed by the Federal Emergency Management Agency (FEMA) using the current 100-year flood maps do not yet include projected impacts from climate change. A risk assessment workshop run by Connecticut's Department of Environmental Protection, with participation from working group members, assigned a high risk level for all infrastructure categories except water supply and indicated that these risks would begin to materialize by 2020 in most categories. Stormwater infrastructure, specifically, has been built to a design standard far too limited to accommodate the projected volume of rain by mid-century. Record storms in spring 2010 washed out culverts, resulting in bridge collapses and flooding throughout coastal communities. Storm impacts to the coastal route forced Northeast Corridor public transit lines out of service for several days, making it increasingly clear that transit—a significant element of a GHG mitigation strategy—is also one of the most vulnerable support systems that will require early adaptation measures.

Natural resources and landscapes form the backbone of the state's quality of life and, in turn, its economy. Not surprisingly, the most susceptible ecosystems are those that operate in a narrow niche and are limited in their geographic coverage, such as coldwater streams, tidal marshes, beaches and dunes, and freshwater wetlands. These also are among the environments that provide human settlement with the greatest ecological services—conditions that support necessary aspects of the state's food web and also buffer human settlement from storms and coastal impacts. Temperature, drought, inward migration of inundated areas, and increased runoff all jeopardize the ability of these fringe ecosystems to support necessary biodiversity and geophysical functions.

Public health extends beyond the literal health of the community to address those necessary aspects of settlement that support human life and reduce the risk of disease. Extreme storms with the potential to knock out power and destroy homes and commercial buildings can lead to temporary homelessness or the inability to reach necessary services, such as food supplies and medical assistance. Both late-summer tropical storm and an unseasonably early snowstorm in 2011 knocked out power for nearly 800,000 households and raised a stark awareness of the potential impacts of increasingly volatile weather. Many commercial areas and downtowns were unaffected because of lower tree cover or underground power lines, so they were able to provide services at local restaurants and hotels. However, it is not difficult to imagine a scenario in which storm refugees cannot reach such assistance. At the same time, nonacute factors related to air quality, urban heat island, and ozone conditions take a lasting toll through asthma and other decreases in lung function or inflammation of airways, which tend to affect urban dwellers and poorer communities disproportionately. These neighborhoods are already more susceptible to the health threats of current pollution than are the more metropolitan residents, and that situation will be compounded by climate change.

Though the draft strategies and implementation plans have yet to be released, the four groups presented initial recommendations with a common theme: the need for better data. The state will require two categories of information to prioritize actions based on finding the appropriate balance between cost and minimization of risk. First, a more detailed review of the impacts of climate change on Connecticut's specific geographies and ecosystems is essential to understand future challenges. Second, specific information on current conditions, such as the exact height of rail infrastructure or exact location of biodiversity resources, is needed to understand what is at risk.

New Jersey

The final recommendations report mandated by the New Jersey Global Warming Response Act of 2007 includes a chapter on adaptation (New Jersey Department of Environmental Protection 2009). It describes the need to plan for the inevitable impacts of climate change and the planning process to identify areas of risk and reduce the state's vulnerability over the next century. This process is to be inclusive and involve representatives from government, business, academia, and the civic community. Six areas for further research and planning align closely with Connecticut's recommendations, but they are organized slightly differently and some important elements are added.

Despite the report's lack of depth in terms of adaptation planning, it presents some specific recommendations of interest. These include a Blue Acres program to purchase storm-damaged properties for recreation, as well as stormwater or coastal impact management and rolling coastal easement programs so that state-controlled coastal buffers migrate inland as the area in need of regional management changes over time.

Two considerations not included in other adaptation plans in the New York region are potential increases of in-migrants to New Jersey and impacts on the state's investments. In an era of universal climate impacts, the Northeast may experience fewer adverse consequences than other regions, so the report suggests the need to plan for significant migration into the region from other parts of the country. Additionally, many of New Jersey's financial resources, including pension funds and other aspects of its portfolio, are invested in areas and sectors that could be vulnerable to the ramifications of climate change. A necessary step in adaptation will be to redirect investments to sectors that will be less prone to losses related to climate impacts.

Regional Agencies

Two regional infrastructure agencies, the Port Authority of New York and New Jersey (PA) and the Metropolitan Transportation Authority (MTA), also are conducting adaptation planning. Recognizing that the majority of its infrastructure lies within or directly adjacent to the City of New York, the PA (2011) is working closely with the city through the NPCC and PlaNYC 2030 on adaptation strategies. It also has specific initiatives underway at its airports, which are very susceptible to rising sea levels and storms, even in the short term. In 2008 the MTA (2008; 2009) convened a Blue Ribbon Commission on Sustainability that focused on the opportunities available to reduce electricity demand within the system, among other measures. It calls for attracting two-thirds of projected population and employment growth into transit-oriented centers organized around the MTA's subway, commuter rail, and bus networks. Given the susceptibility of the subway and rail infrastructure to coastal impacts and inundation, the MTA has also created an internal adaptation team to identify appropriate planning and response strategies to limit the impact of climate change on the critical infrastructures they manage (Jacob 2001; MTA 2009).

New Consortium for Sustainable Development

In the winter of 2010, officials from several major cities in the tri-state region began to discuss a collaborative approach to economic development. With a shared set of assets, including robust transit, walkable downtowns, housing options, and innovative economies, representatives from Newark, New Jersey, New York City, and Stamford, Connecticut, recognized that together they had a set of complementary skills that could increase their joint competitiveness dramatically by building a stronger network. Concurrently, the federal government was beginning to take a new approach to coordinating planning among its agencies through place-based programs to benefit regions already implementing policies to achieve livable communities.

Regional Plan Association (RPA) and the original cities that met to enhance their shared competitiveness led the formation of a new consortium to attract federal financial support. The New Jersey representatives eventually went their own way, but the New York–Connecticut Sustainable Communities Consortium eventually included four metropolitan planning organizations: the New York Metropolitan Transportation Council plus three Connecticut-based groups, the Southwestern Region Metropolitan Transportation Organization, Greater Bridgeport–Valley Metropolitan Planning Organization, and South Central Council of Governments.

Nine cities—Bridgeport, New Haven, Norwalk, and Stamford in Connecticut; Mount Vernon, New Rochelle, White Plains, and Yonkers in New York's Hudson Valley; and New York City—two New York counties (Nassau and Suffolk on Long Island), and two regional planning organizations (Long Island Regional Planning Council and RPA) were also involved. With approximately

15 million residents and a regional annual economy greater than $800 million, this consortium was the largest in the country to receive support for regional planning from HUD.

This new effort includes both regional and local components. At its heart is a network of transit-oriented developments that collectively can increase the amount of location- and energy-efficient housing dramatically. Each of the projects presents hundreds of acres of underutilized land and brownfields that can house the next generation of the region's residents in transit-rich and sustainable neighborhoods. These plans comprise the metropolitan area's greatest opportunity to reduce vehicle miles travelled and the resulting transportation emissions significantly. These new neighborhoods, within walking distance of the nation's most robust transit network and the largest concentrations of employment outside of Manhattan, will form the foundation of a regional mitigation strategy by means of interventions to the built environment.

Acknowledging the need to adapt to inevitable climate impacts, this initiative will enable the region to take its most significant step toward confronting this challenge. Using New York City and its miles of coastline as a test case, the consortium will conduct an analysis to determine the best strategies to increase the area's resilience to sea level rise and coastal storm effects. This planning process and the lessons learned will be replicable in communities throughout the tri-state region and the nation, and will set the benchmark for preparing communities to manage the trade-offs as coastal cities continue to grow during the twenty-first century.

Toward a Coastal Adaptation Strategy

Despite making progress in developing climate adaptation strategies, the New York region is still threatened by potentially catastrophic impacts of climate change, and its highly decentralized governance structure makes it difficult to develop a comprehensive climate adaptation strategy for the entire metropolitan area. While the incremental steps now being taken by all three states, many municipalities, and major public authorities can lead to a broad system of adaptation measures, these efforts may not be adequate to meet the challenges posed by the most severe projected impacts.

Three broad categories of adaptation strategies will have to be implemented in coordination with one another and at different levels of government to prepare the New York metropolitan region for sea level rise and storm surge: retreat, resilience, and protection. Retreat and resilience must begin immediately across the region, and planning for protection must accompany assessments of the changing impacts of the first two categories.

Considering Strategic Retreat

As sea levels rise and as coastal storms and storm surges increase in frequency and intensity, some portions of the coastline will not be able to continue to support human habitation. Although property values along the region's entire coast are high, some areas will not be able to justify the significant investment needed to prevent repetitive loss of value from storm impacts. Two tests should be applied to determine whether additional public resources should be deployed for the protection of vulnerable areas. The first test would determine if critical infrastructure of regional and local significance, such as transportation, energy, or wastewater treatment facilities, is present and needs to be reinforced. The second test would determine whether the concentration of employment, housing, and other activities is such that the revenues generated in those areas are high enough to offset public costs associated with repeated reconstruction following floods or other disasters. Low-density residential and second-home communities without critical infrastructure would be the most likely targets for relocation and retreat.

This strategy could be implemented through administratively simple (but politically difficult) changes in federal flood insurance and disaster relief programs that would preclude rebuilding in flooded areas following major storm events. Residents receiving flood insurance or disaster payments would be required to reinvest these funds outside of designated retreat areas. In addition, local, state, and federal beach nourishment, flood prevention, and infrastructure investments would be prohibited in these areas. Because of the political challenge inherent in withdrawing public support from flood-prone areas, it may be necessary to phase in these policy changes following major flood events.

Analysis at the regional or state scale is necessary to determine which communities will be most susceptible to climate impacts and which ones are likely to have the greatest imbalance between the cost of postdisaster public bailouts and future tax revenue. To build political support for these actions, it may also be necessary or desirable to create transfer of development rights (TDR) programs to provide financial incentives for relocating development away from flood-prone areas to safe upland districts. TDR programs have been utilized in a variety of urban and suburban settings across the Northeast to achieve similar outcomes, but some ingenuity will be required to adapt these programs to this new policy goal.

Increasing Regional Resilience

Many stretches of the coastline contain critical, immovable infrastructure, and other areas have concentrations of high-value development and dense populations that preclude relocation or any market-based transfer scheme. Some communities have both types of resources, and all of them will need to be made more resilient to potential climate impacts so that temporary flooding, heavy rains, and storm surges can be absorbed by the built environment in a way that results in temporary inconvenience rather than long-term damage. Much of the region's urban transportation, wastewater, and electricity generation infrastructure is located just above—or often below—sea level. This resilience strategy will combine a variety of actions that typically are implemented at the site level and target protection efforts taking a different approach to development in the path of potential flooding to work with water rather than against it.

Site level protection can take many forms, but it must always involve small-scale design interventions that remove critical pieces of the region's infrastructure from the path of flood events. The two broad types of intervention involve (1) creating small barriers to water intrusion and (2) removing elements from the path of water. The subway systems of New York City and Newark, for example, are located largely below ground and many sections are below sea level. For all but the most significant events, small and simple changes in design can prevent a deluge from cascading down stairs and into the portals of these subway systems.

At the new South Ferry subway station at the southern terminus of the #1 train, or 7th Avenue Local line, the subway portal was raised one step (approximately eight inches) above sidewalk level so that a passenger steps up once before descending the staircase into the system. This additional step essentially serves as a miniature levy, protecting this portal from surrounding waters. Similar interventions could be instituted on the roadways surrounding highway tunnels, in the form of speed humps, and at a larger scale in the form of dikes situated around airport runways and energy and wastewater facilities.

To remove aspects of infrastructure from the path of water, electrical devices, computer systems, and other critical support systems for buildings or infrastructure could be raised to a height sufficient to place them above projected flood levels rather than being situated at or below ground level. Working with water in these ways creates a site level design paradigm that enables buildings and infrastructure to manage water rather than attempt to block it or to funnel it into stormwater collection systems. This approach has benefits in dealing with both increased storm intensity and coastal storm surge. As rain events become more severe, stormwater will need to be collected and retained on site in order to avoid combined sewer and stormwater overflows and flooding. All aspects of green infrastructure, including green roofs, rain barrels, rain gardens, street trees, and permeable pavement, should be implemented on private parcels and in public rights-of-way. These measures should be mandated in critical basins and incentivized throughout the region.

Within the floodplain and the coastal impact zones, the ground floors of buildings should be designed to be flooded without serious mechanical or property damage. Roadways along water bodies should act as temporary reservoirs for increased flow, and their drainage should be designed to fulfill this role. Living quarters and mechanical systems should be at elevations above the potential flood height to limit damage. The current building codes in New York City and many other parts of the region already include such specifications for future development, but it will be necessary to retrofit existing buildings to meet these standards as well. While urban design objectives of active ground floors and walkable waterfronts may be in conflict with raising active uses above the flood line, these difficulties can be overcome when both adaptive responses and good urban design are planned in conjunction from the outset.

Building Protection

Regardless of how successful retreating from the most vulnerable coastal areas and making critical infrastructure and densely developed areas more resilient prove to be, in the long run the region may require the kind of flood barriers already installed in some other developed countries, such as the Netherlands, United Kingdom, and Japan. Given the lead time needed to construct such a complex system, the region should have begun to assess the need for such actions already.

Professor Malcolm Bowman and his colleagues at the State University of New York at Stony Brook have proposed that retractable flood barriers be erected at three key points around New York Harbor to protect those areas with the highest intensity of development and activity at the region's core. To protect the entire harbor, barriers would need to be erected at the Verrazano Narrows, at Arthur Kill in Perth Amboy, New Jersey, and near the Whitestone Bridge, where the Upper East River flows into Long Island Sound (Bowman et al. 2004). This system would prevent storm surges from flooding the most densely populated, low-lying, and flood-prone areas around the harbor's Upper Bay, the Lower Hudson and East Rivers, and Newark Bay. An additional barrier would likely need to be constructed at the gateway to Jamaica Bay between Rockaway Beach and Coney Island to protect vulnerable Queens neighborhoods in addition to those of Manhattan, the Bronx, Brooklyn, Staten Island, and New Jersey that the three core barriers would protect.

The SUNY Stony Brook researchers have modeled the barriers' projected ability to protect the urban core against the impacts of storm surge events using three sea level rise scenarios—3.7, 9.7, and 17.8 inches—to approximate conditions in 2030, 2050, and 2080 (Kim, Simmons, and George 2009). The barriers would reduce the maximum water height within the walls by 60 inches and would increase the outside height only up to 8 inches as the water tapers off rapidly into the sea. Results would include reductions of flooded land by 25 percent, affected population by 20 percent, property value impacts by 35 percent, and hazardous material and waste sites impacted by 50 percent (Kim, Simmons, and George 2009). The value to the region would be immense, though the cost would be tremendous and no clear quantification of the cumulative impacts of retreat and resilience measures has been performed.

Given the long timeframe of construction, cost estimates for these structures are neither comprehensive nor definite, but some numbers are available. The Verrazano Narrows storm surge barrier linking Staten Island and Brooklyn was estimated in 2009 to cost approximately $6.5 billion with an estimated annual maintenance cost of $75 million (Jansen and Dircke 2009). Combining that harbor-entrance barrier with lower-cost designs for narrowing the East River and Arthur Kill waterways could protect the entire harbor at a total cost of $10 billion. Despite the magnitude of the threat, the probability of severe events actually occurring remains relatively low. Many other policy demands compete for the resources necessary to pay for these barriers. Consequently, no action has been taken on these proposals, but more in-depth studies are necessary and should be coordinated across state lines in the coming years. This analysis will be increasingly important as the potential benefits of the existing shorter-term actions and site-level strategies are better understood.

The experience in cities that have erected flood barriers suggests that repeated devastating floods must occur before political support can be galvanized to invest huge sums in these systems. London's Thames Flood Barrier was erected after ruinous flooding in 1921 and 1953. The Dutch Delta Works system of flood barriers was built following the catastrophic floods of 1953, when 1,800 people died and extensive property damage occurred. Similarly, the hurricane barriers in Stamford, Connecticut, Providence, Rhode Island, and New Bedford, Massachusetts, were built only after disastrous flooding was caused by major hurricanes in 1938 and 1955. It may be that in New York, too, experiencing an extreme event will be necessary before progress in building flood barriers is made.

If climate change and sea level rise forecasts prove to be accurate, it is only a matter of time before such events will occur. Thus, it is prudent to be prepared to protect the tens of millions of people who will be living and working in the New York region in the years and decades to come. Both immediate responses and long-term planning are necessary to prepare the region for the challenges the region will face in a new and changing climate.

A Regional Approach

Just as the GHGs emitted by power plants, transportation systems, and buildings do not respect political borders as they enter the atmosphere, the impacts of global warming are indiscriminate in their geographic distribution. In nearly every state and local plan beginning to tackle this challenge, policy recommendations tout a regional approach. Yet to date the initiatives neither demonstrate cooperation nor share significant information across state or other jurisdictional lines. The Regional Greenhouse Gas Initiative (RGGI) was established to acknowledge that the northeastern states are tied to one another in their quest to reduce GHG emissions within this region, and these states also must work together on an adaptation strategy.

The New York metropolitan area's coastline spans Connecticut, New York, and New Jersey, and the river corridors that will flood during intense storm events are shared with several states beyond the borders of the tri-state region. Partnerships among various governments will be necessary to address the challenge of climate change. For example, the threat of coastal impacts along the

Atlantic Seaboard could be managed more effectively by collaborative efforts among New York, New Jersey, Rhode Island, Delaware, and other states. The coastal impacts along Long Island Sound are best dealt with by a partnership between New York and Connecticut. The critical infrastructure of New York City and its harbor is of importance to the states and authorities of the tri-state region in addition to the federal government. Mitigation planning has demonstrated that local initiatives become increasingly effective when municipalities partner at the regional scale. A partnership that involves states at the megaregional scale—the scale of the Northeast—will be more effective at achieving adaptive action than policies enacted by any one state individually.

While some U.S. metropolitan regions spill into adjacent states or occur along a river border between states, only New York spreads across a geography that takes in more than three states with hundreds of miles of coastline and the bulk of its population concentrated on three low-lying islands. The larger Northeast Megaregion consists of a continuous, urbanized corridor along a vulnerable coast across 14 states and the District of Columbia. The interdependence of these communities has led to their success over the past half-century, and collaborative planning for climate adaptation will help prepare both the Northeast Corridor and the New York metropolitan region to face the changes of the next 50 years or more. Failing to work together across political boundaries in a calibrated response to the risks associated with global warming will jeopardize not only the economic competitiveness of this region but its habitability for generations to come.

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Figure 2.1 Southeastern Atlantic Coast States

Source: Weiss and Overpeck, University of Arizona

dark blue overlay areas = low-lying coastal areas of ≤ one meter elevation vulnerable to future sea-level rise

Chapter 2

Southeastern Atlantic Coast States

Lauren Brown, Colin Quinn-Hurst, Phil Emmi, and Reid Ewing

The southeastern Atlantic coast of the United States, with low-lying topography in the path of Atlantic Ocean weather, is particularly vulnerable to sea level rise and extreme weather events (figure 2.1). The region already experiences floods, coastal erosion, wildfires, droughts, and hurricanes. Anthropogenic climate change and rising sea levels are likely to result in increases in both the frequency and severity of extreme weather events as well as in associated impacts on coastal communities (Nicholls et al. 2007). Both population growth in coastal areas and the limited land available for development lead to significant human exposure to natural disasters throughout the coastal states (McMullen and Jabbour 2009; U.S. Global Change Research Program 2009). From North Carolina to Florida, such threats hold implications for economic, social, and environmental policy, to which they are just beginning to respond.

Impacts of Climate Change

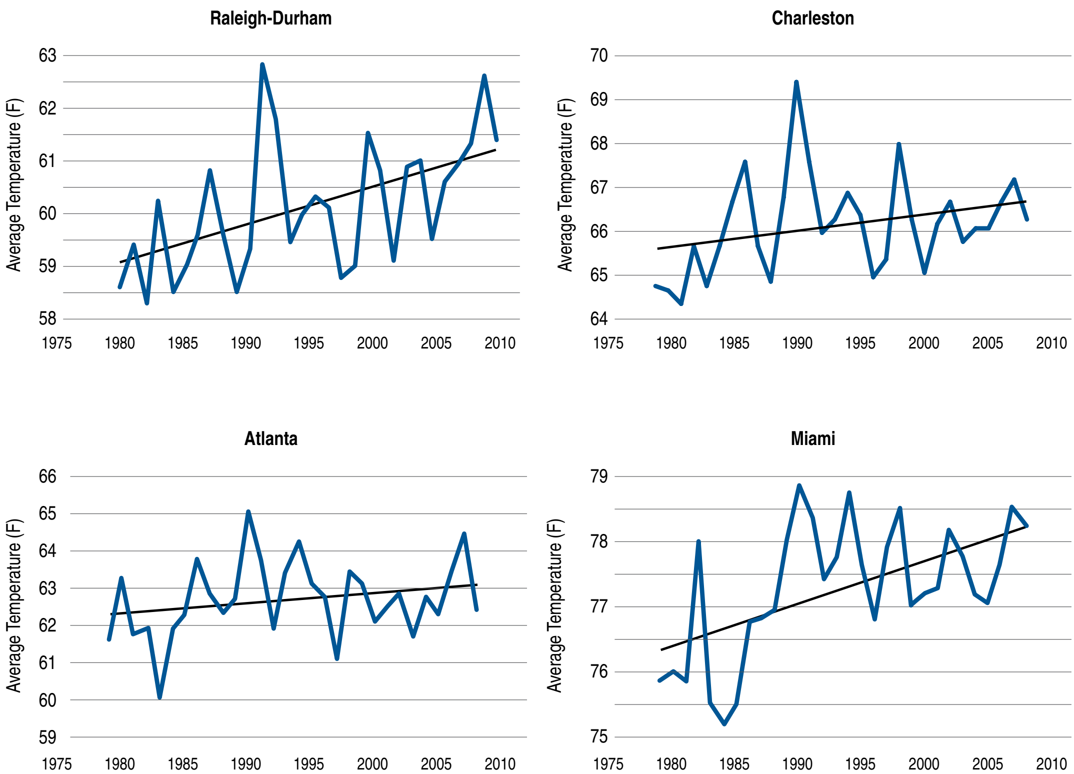
Temperature Rise

Based on trend lines, over the past 30 years average annual temperatures in the Southeast have already risen between 1°F and 3ºF. The examples in figure 2.2 are typical for the region. As modeled by the Intergovernmental Panel on Climate Change (Meehl et al. 2007, 762), average global temperature would rise 2.0°F to 5.2ºF by 2100 in the best-case scenario, and this assumes a coordinated global shift toward clean technology and an information-based economy. The worst-case scenario—an associated temperature rise of 11.5ºF over the next century—assumes continued industrial globalization that remains dependent on fossil fuels (Meehl et al. 2007).

Though regional variations in temperature are difficult to project, the southeastern states can anticipate continued warming across all seasons. Temperatures are projected to rise 4.5°F by 2080 under a low emissions scenario, and 9°F under a high emissions scenario. The number of very hot days—those exceeding 90°F or 100°F—is expected to rise faster than the number of days with average temperatures, putting extra stress on people, agriculture, livestock, ecosystems, transportation, and other infrastructure (U.S. Global Change Research Program 2009). Florida, for example, could have more than 165 days

Figure 2.2 Annual Average Temperatures at the Airports in Raleigh-Durham, Charleston, Atlanta, and Miami

Data source: NOAA http://www7.ncdc.noaa.gov/IPS/



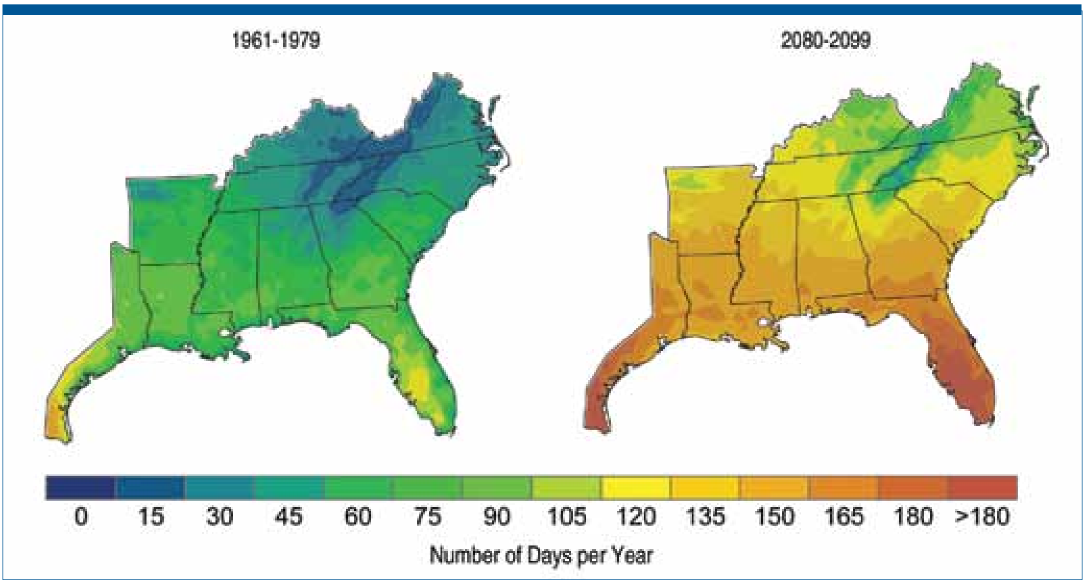
per year over 90°F, a 275 percent increase from the roughly 60 days experienced during the 1960s and 1970s (figure 2.3).

Recent research both confirms the conclusions of the IPCC's Fourth Assessment Report, published in 2007, and indicates a more rapid rate of change in global mean temperature (Allison et al. 2009; McMullen and Jabbour 2009). Carbon dioxide has accumulated in the atmosphere faster than predicted even in the worst-case scenario, and this has led to faster-than-expected temperature rise and more pronounced "fingerprints" of climate change, such as sea level rise, ocean acidification, and increases in storm severity (Emanuel, Sundararajan, and Williams 2008; Rahmstorf 2007).

Sea Level Rise and Flooding

Under all future scenarios, warming trends increase the temperature of the oceans, which absorb the majority of heat associated with global warming. Increases in ocean temperature lead to sea level rise, heavy precipitation events, and shoreline erosion (McMullen and Jabbour 2009; Stanton and Ackerman 2007).

Figure 2.3 Days per Year with Peak Temperature Exceeding 90°F
Source: U.S. Global Change Research Program (2009, 112).



The IPCC Fourth Assessment Report (Meehl et al. 2007) predicts by 2100 a sea level rise from 0.18 to 0.38 meters (m) under the best-case scenario and from 0.26 to 0.56 m at the worst-case scenario. The IPCC affirms only limited sea rise over the course of the twenty-first century because no consensus has been reached regarding quantifiable effects of dynamic ice change in glaciers, ice caps, and continental ice sheets (McMullen and Jabbour 2009).

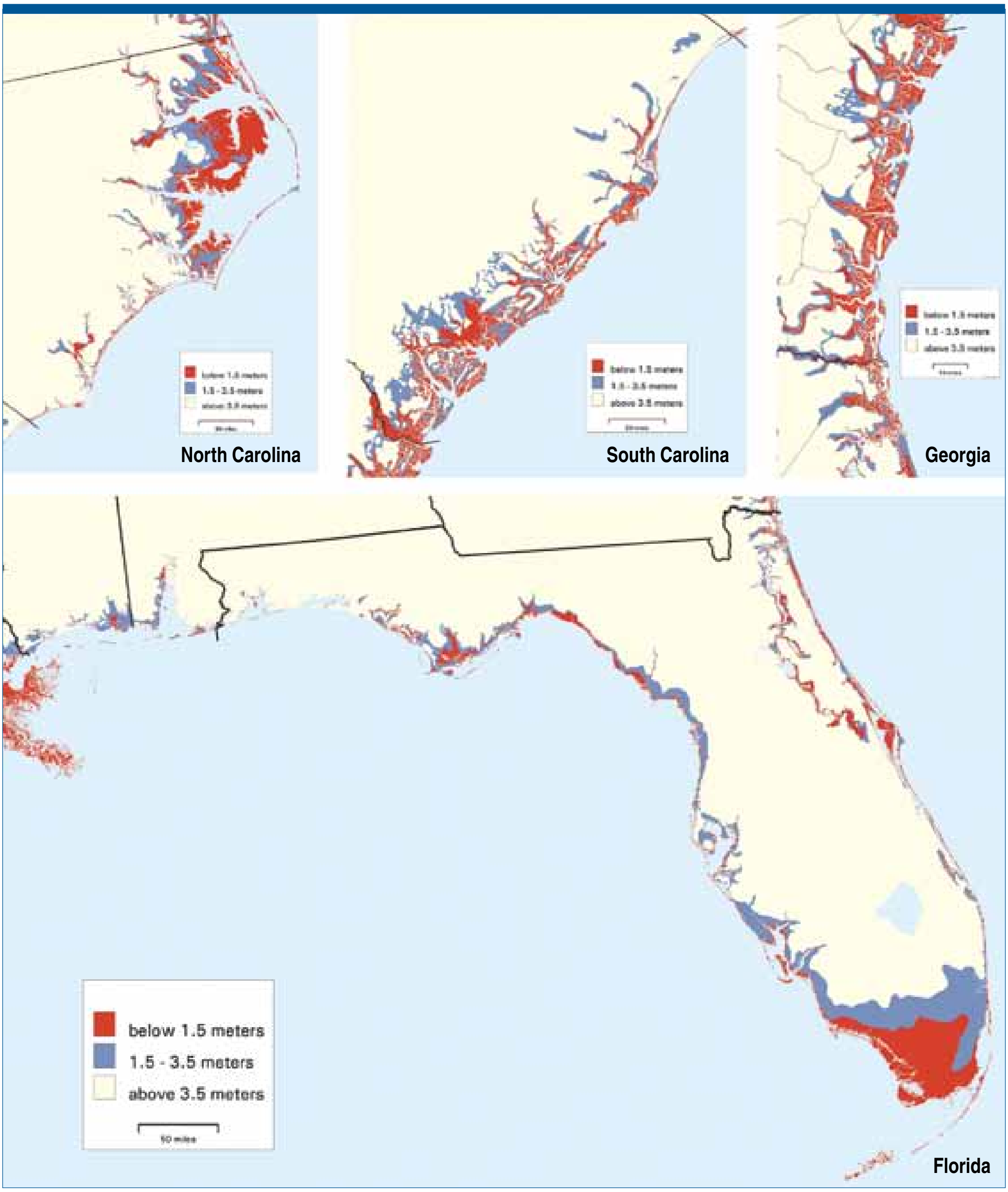
Since publication of the IPCC Fourth Assessment Report, the question of future sea level rise has been studied extensively. Loss from glaciers is now occurring at nearly twice the former baseline rate. Measurements also show an increasing rate of ice discharge from the Greenland and Antarctic ice sheets (Allison et al. 2009). While no precise methods for modeling future contributions to elevated sea levels from dynamically changing glaciers, ice caps, and ice sheets, have been agreed upon, twenty-first century limiting values have been estimated (table 2.1).

Locally, the impacts of sea level rise vary according to the rate of rise relative to adjacent shorelines. While some portions of the U.S. coast currently experience rising land mass, the majority of shorelines are subsiding by up to 0.6 m per century (Milne et al. 2009). Over the past half-century, relative sea level

Table 2.1 Differing Estimates of Global Sea Level Rise

Author	Sea Level Rise by Year 2100
Meehl et al. (2007)	0.18–0.59 m (7–23 in.)
Rahmstorf (2007)	0.5–0.14 m (20–55 in.)
Solomon (2009)	0.4–1.9 m (16–75 in.)
McMullen and Jabbour (2009)	0.79–2 m (31–79 in.)

Figure 2.4 Land Vulnerable to Sea Level Rise on the Atlantic Coast of Southeastern United States
Source: Titus and Richman (2001).



rise along the Southeast's Atlantic coast has been on the order of 0.05 to 0.1 m. Local variation beyond this range is typically due to subsidence and may be found near Charleston, South Carolina, where relative sea level rise has been 0.15 m over the past half-century (U.S. Global Change Research Program 2009).

James G. Titus and Charlie Richman (2001) prepared maps of the Atlantic coastal areas of the southeastern United States that are vulnerable to sea level rise and include lands inundated by sea level rises of 1.5 m and 3.5 m, as seen in figure 2.4. Most of the coastal areas affected are depositional landscapes and intertidal wetlands.

The vulnerability of Florida's southeastern coast is clear, including populated areas such as Fort Lauderdale, Miami, and Miami Beach (Stanton and Ackerman 2007). Figure 2.5 reveals in detail the hazard imposed in four coastal regions by a 1-meter sea level rise.

Hurricanes and Storm Surges

Due to climate change, hurricanes will likely become more intense, with higher peak wind speeds and heavier precipitation. Examination of historic hurricane records from the past 50 years shows a pronounced upward trend in hurricane power and frequency. Emanuel, Sundararajan, and Williams (2008) have linked the increasingly intense cyclone activity in the North Atlantic basin to rising tropical sea-surface temperatures. Incremental changes in sea level lead to large increases in heights during extreme storm events. Even with a moderate sea level rise (below the predictions in the IPCC Fourth Assessment Report), extreme storms that are currently expected to occur every 100 years will begin to occur every several months (Hunter 2008).

Figure 2.5 Sea Level Rise and Inundation of Coastal Communities at a Rise of 1.0 meters

Source: Architecture 2030 (2009). Images © 2007 Google and © 2008 2030, Inc.

The vast majority of Florida's population is settled near the coast, so increased storm activity will directly impact nearly 95 percent of residents living in areas that have not been built to withstand the projected storm intensities (U.S. Global Change Research Program 2009). Additionally, a significant amount of the state's key infrastructure—including roadways, ports, and water treatment facilities—is also located near the coast. This pattern of infrastructure placement puts the functional resources of the state at risk from both rising sea level and storm surges.

Loss of Beaches and Wetlands

Areas most vulnerable to rising sea levels include depositional landscapes, such as beaches, barrier islands, and spits; and intertidal wetlands, such as salt marshes, sandflats, mudflats, and mangroves. Generally, sea level rise deepens coastal waters, increases the size of breaking waves, and accelerates erosion of the depositional landscapes. Barrier islands will experience more intense erosion of seaward edges, more frequent wash overs, and a landward drift of residual dunes. Narrow beaches are likely to disappear altogether, and beaches fronting salt marshes or lagoons will be over washed, while landward landscapes will be invaded by the sea.

The Bruun rule posits that the extent of landward beach-profile recession will be from 50 to 100 times the rise in sea level; thus, for every meter of increase in sea level rise, beaches will recede by 50 to 100 m (Bruun 1962). Many resort beaches are less than 30 m wide, and following the Bruun rule, that type of beach could be inundated by a half-meter sea level rise—an eventuality that could occur by mid-century if McMullen and Jabbour's (2009) predictions prove accurate.

Although historically dismissed as swamps and often drained for development, intertidal wetlands have come to be widely recognized for the important ecosystem services they provide. Wetland soils and vegetation contribute to greenhouse gas (GHG) mitigation through intensive productivity. They retain, recover, and remove excess nutrients and pollutants from stormwater, and they also aid in soil formation and nutrient cycling, providing a broad diversity of habitat for resident and migrating species. Beyond that, they stabilize shorelines by reducing erosion, dampen storm surges, dissipate strong winds, protect against flooding, and reduce damage to life and property during severe storms (Daily et al. 1997; Mitsch and Gosselink 2000).

Though considerable uncertainties remain for predicting how the southeastern coast will respond to the effects of climate change, many scientists agree that coastal wetlands have tipping points. When their limits are exceeded, congruent landforms become unstable and undergo irreversible changes (Cahoon et al. 2009).

Growth of wetland vegetation can adapt to a degree of change in sea level. In intertidal zones, for example, salt marshes have been seen to alter their elevation relative to sea level by trapping sediment loads and accumulating vegetative detritus. Under certain conditions, salt marshes may be able to keep ahead of rising sea levels through a process of accretion. Marshes will respond more actively in parts of the South Atlantic coast, where nutrient and sediment loads tend to be high. If sea level rise occurs at a slow rate, a marsh will both elevate itself and migrate slowly inland. Its capacity to do this is maintained so long as relative sea level rise does not exceed 1.2 centimeters per year (Morris et al. 2002). This capacity may protect selected wetlands during the early years of the present century, but may fail should sea level rise accelerate beyond identified thresholds as is expected (Tibbetts 2007).

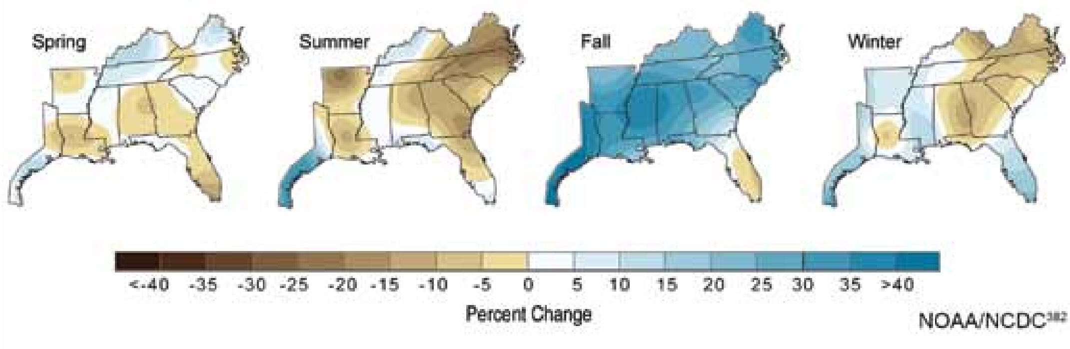
Mangroves represent an important wetland type in South Florida. In regions with little sediment input, the maximum rate of relative sea level rise that mangroves can sustain is estimated to be 0.2 m or less per century, or less than 2.23 mm per year. Present rates of sea level rise in the region range between 2.03 mm per year at Naples and 2.79 mm per year at Vaca Key (Zervas 2009). Thus Florida's mangroves may well fail as sea level rise accelerates beyond the 2.23 mm per year threshold (Twilley 2007).

In addition to the vulnerability of coastal landforms, rising seas are also likely to leave large urban areas such as Miami-Dade County susceptible to storm damage as wetlands and mangroves are lost. This, in turn, may affect the county's water supply as ocean water reaches the Biscayne aquifer (Miami-Dade County 2007). Warmer temperatures, rainfall variability, and coastal inundation are apt to increase saltwater intrusion and elevate groundwater salinity, particularly in areas with limited freshwater recharge (Scavia, Field, and Boesch 2002).

Drought and Wildfires

Higher temperatures, surface water evaporation, and increased variability in rainfall can all lead to drought, which now represents a distinct threat to southeastern states (figure 2.6). While average precipitation in the Southeast has increased by 30 percent since the early 1990s, summer and winter precipitation declined by nearly 10 percent in the eastern part of the region. Over recent decades the percentage of the Southeast region experiencing drought has increased. Despite a projected overall increase in annual rainfall due to high-precipitation events, consistent moderate rainfall will decrease, which can impact the recharge of freshwater aquifers (Stanton and Ackerman 2007). Such circumstances contributed to the drought in Georgia in 2007 and led to $1.3 billion in economic loss (Flanders, McKissick, and Sheperd 2007). An association also exists between wildfires and climate change. As hotter, drier summers combine with the spread of insect species that negatively impact tree health, large amounts of dry, dead wood ripe for burning are created.

Figure 2.6 Seasonal Change in Rainfall, Southeastern United States, 1901–2007
Source: U.S. Global Change Research Program (2009, 111).



State Responses to Climate Change

Even though the southeastern coast of the United States is currently among the nation's least developed regions, it contains one-third of its fastest growing counties. Much of the growth is concentrated along the coast, where sea level rise and increased storm intensity will affect land use and development. This growth often takes the form of urban sprawl with its low-density, single-use development that generates high vehicle miles traveled (VMT) and elevated demands for residential space cooling, all of which contribute to climate change (Ewing et al. 2008). Currently, the four southeastern coastal states contribute a significant percentage of the country's GHG emissions. From 2000 to 2005, southern cities and suburbs increased their carbon footprints faster than any other region of the country (Brown, Southworth, and Sarzynski 2008). Given these patterns, the region now recognizes the need to address climate change through both adaptation and mitigation, and state efforts are currently underway.

Florida

Due to its low-lying topography and susceptibility to tropical storms, Florida is especially vulnerable to sea level rise and extreme weather events. The state's main adaptation strategies focus statewide on these risks, and some local governments have adopted these approaches in their own plans. Florida's mitigation strategies are some of the most ambitious in the country, and many Florida cities and counties also participate in nationwide initiatives such as the International Council for Local Environmental Initiatives' (ICLEI) Local Governments for Sustainability program and the Mayors' Climate Protection Agreement.

In 2007 Governor Charlie Crist signed a set of three executive orders—07-126 through 07-128—aimed at reducing Florida's GHG emissions and increasing its energy efficiency. The first required the Department of Environmental Protection (DEP) to create a GHG measurement system and an environmental scorecard for the state and set a goal for 40 percent emissions reduction by 2025. Executive Order 07-127 required electric utilities to reduce emissions back to 2000 levels by 2017, to 1990 levels by 2025, and 80 percent below 1990 levels by 2050. It also adopted a 22 percent reduction in vehicle emissions by 2012 and a 30 percent reduction by 2016.

The final executive order created the Governor's Action Team on Energy and Climate Change, which went on to establish a statewide climate action plan that addressed both adaptation and mitigation. During the 2008 legislative session, the governor and legislature created the Florida Energy and Climate Commission, the appointed members of which implemented the action plan by conducting annual assessments. The commission also ran incentive programs and provided policy recommendations to the governor and legislature.

Additionally, the U.S. Department of Energy, Florida Energy Office, and Florida Green Building Coalition worked together to create the Green Local Government Designation Standard. This voluntary standard offers a comprehensive list of strategies to achieve GHG reduction and provides guidelines for education programs, ordinances, and incentives for sustainable development.

To address coastal areas and population growth in other high-hazard locations, the Florida Coastal High Hazard Study Committee has recommended management strategies for critical erosion, shoreline change, and beach management. Though originally not intended to address sea level rise and increased storm intensity, the committee's reports have recommended restricting development from hazardous shoreline areas, thus promoting an important adaptation strategy. To deal with intensified drought conditions, the state's 2007 Drought Action Plan includes relevant adaptation measures including the reuse of reclaimed water, the capture and reuse of agricultural irrigation water, and seawater desalination.

Florida's Energy and Climate Change Action Plan. This plan's final report outlines 50 specific policy recommendations for energy supply and demand, cap-and-trade plans, transportation and land use, agriculture, forestry, waste management, and government policy and coordination (Center for Climate Strategy 2008). If all strategies were implemented, the state would surpass by 34 percent the GHG emissions reduction goals set in the governor's executive orders (table 2.2).

The plan begins with a climate science research agenda and a scientific advisory council that will advise state government on research matters. It then identifies and establishes long-term funding to support research with the aim of protecting this funding from short-term economic or political cycles. The research agenda seeks to conduct climate assessments necessary for the protection of Florida's ecosystems and biodiversity and to enhance support for mapping, monitoring, and modeling of climate impacts.

Table 2.2 Florida's Annual Emissions: Reference Case Projections and Impact of Action Team Recommendations

Source: Center for Climate Strategy (2008, 15).

Annual Emissions (MMtCO2e)*	1990	2000	2005	2017	2025
Reference case projections	248.8	315.0	336.6	405.0	463.3
Reductions from recent actions (Exec. Order 07-127)				40.6	108.7
Projected GHG emissions after recent actions				364.4	354.6
Target emission levels				315.0	248.8
Total GHG reductions from action team recommendations				82.6	189.8
Difference between action team reductions and target emission levels				-33.2	-84.0
Projected annual emissions after quantified action team reductions				281.8	164.8

**MMtCO2e = million metric tons of carbon dioxide equivalent*

Florida's plan also addresses local comprehensive planning, with regional agencies providing financial and technical assistance to local governments in order to ensure timely updates of local plans. It supports local government review of coastal management elements so that necessary amendments that will enhance coastal resilience in the face of sea level rise will be identified. Regarding the Florida Administrative Code and other statutes, regulations, and, policies, the plan seeks review by the state's attorney general to determine potential conflicts between private property rights and the responsibility of state and local governments to safeguard communities.

Protection of ecosystems and biodiversity takes center stage in Florida's approach. The state's plan aims to ensure the health and resilience of Florida's terrestrial, freshwater, and marine natural communities through redundant representation of habitats and species and protection of connecting corridors. The plan also discourages future reliance on bulk hardening, or reinforcement, to stabilize estuarine and beach shorelines, stating that shoreline hardening should be considered only after completion of a cumulative assessment of impacts on coastal ecosystems. Additionally, the plan supports policies and regulations that clearly define when, how, where, and under what circumstances emergency beach stabilization is allowed.

Regarding fish and wildlife, the plan supports assessment of vulnerability to climate change, identifying the most vulnerable species in order to enhance their chances of survival over the next 50 years. Water resource management also plays a role, and the plan identifies and quantifies the potential effects of various climate scenarios on existing potable water supplies, emphasizing source water availability and quality.

In addressing the built environment, the plan requires the Florida Building Code to incorporate design criteria that can resist future loads related to climate change and to specify a minimum service life of 50 years. Florida recognizes the need to incorporate adaptation as a design criterion for new infrastructure, making relevant training in architecture, engineering, and construction management a condition for licensing. In a related approach, the plan provides for public outreach through adaptation training and a major public education campaign.

With this suite of strategies, the Florida plan incorporates the best in adaptation and goes further by comprehensively integrating research, planning, ecology, the built environment, and public education. This model plan complements the range of mitigation strategies also pursued by the state. Its integrated and comprehensive approach represents a new state-level standard for addressing climate change in the region.

South Florida. As a planning and public policy agency, the South Florida Regional Planning Council (SFRPC) reviews local governments' comprehensive plans and plan amendments to ensure their consistency with the Strategic Regional Policy Plan. The council also coordinates with the Florida Department of Transportation, other state and federal agencies, counties, cities, and nonprofits to make certain that local plans are consistent with the regional plan. Through energy-related sections of the plan, the SFRPC provides "fuel-neutral" policy direction, by which it seeks to avoid preferential treatment in government policy of one fuel over another. In conjunction with the Florida Gold Coast Clean Cities Coalition, it tracks vehicles using alternative fuels in Broward, Martin, Miami–Dade, Monroe, and Palm Beach Counties.

The SFRPC also prepared a Climate Change Community Toolbox to help decision makers understand how to carry out adaptation planning. In addition to a compendium of current information on adaptation strategies and processes, the toolbox includes a series of maps that consider long-term sea level rise. SFRPC coordinates the Southeast Florida Regional Climate Change Compact, which was adopted by each of the counties as of 2010. The compact includes a Regional Climate Change Action Plan. Goals include establishing a baseline of GHG emissions for the region and coordinating emission reductions from the transportation sector, the built environment, and land use. In early 2011, development of this action plan continued through a series of work group meetings.

Miami-Dade County was one of the first counties in the Southeast to adopt a GHG emissions reduction plan that targets land use, transportation, energy use, and solid waste in order to reduce CO_2 emissions. Officials estimate an annual average reduction of 2.5 million tons of CO_2 resulting from these mitigation measures (Miami-Dade County 2007). In 2008 Miami-Dade also became one of the first counties to join the Cool Counties Program, which calls for an 80 percent reduction in GHG emissions by 2050, thus reinforcing the county's existing efforts in climate change mitigation (Conservation Leaders Network n.d.).

MiPlan, the City of Miami's climate action plan, outlines mitigation strategies to reduce by 2020 the city's GHG emissions by 25 percent below 2006 levels. This plan focuses on emissions reductions available through energy efficiency in buildings, renewable energy, reduced automobile and fossil fuel dependency, and more efficient land use and zoning. Miami is one of the only municipalities in the Southeast to have a local climate action plan that incorporates both mitigation and adaptation.

Miami's Office of Sustainable Initiatives addresses climate change mitigation through energy policy and education. In an effort to reduce carbon dioxide emissions, the city is promoting energy conservation and efficiency within its own buildings. For example, along with its reliance on passive solar energy, Miami City Hall has an efficiency retrofit of its lighting and a 2008 green purchasing ordinance requiring all products bought for city buildings to meet Energy Star guidelines.

Broward County offers GHG inventory training, conducts climate change leadership summits, and issues emissions reduction strategies. It also encourages its 28 city and town governments to sign on to the Mayors' Climate Protection Agreement and to agree to reduce GHG levels by 2012 to 7 percent below 1990 levels. The majority of them have joined. The cities do not state this reduction goal in their own current local plans and policies, however.

The comprehensive plan of the City of Fort Lauderdale includes a section on sustainability. While it never mentions climate change or greenhouse gases, it does cover energy conservation as well as public investments in alternative transportation. The city's environmental initiatives do not refer to climate change either; instead they focus on water, landscaping, and trash recycling.

Central Florida. After signing the Mayors' Climate Protection Agreement in 2007, the City of Orlando created an internal green team made up of staff members from all municipal departments. The team created Green Works, an environmental action agenda and outreach tool that outlines goals and includes efforts to make the city more energy efficient. As part of this program, city and Orange County staff from planning, permitting, facilities, purchasing, capital improvement, housing, and other departments participated in a training course for Leadership in Energy and Environmental Design–New Construction (LEED-NC), and since then a number of LEED-certified fire stations and private sector projects have been constructed.

Georgia

Georgia is one of 12 states in the country that, as of this writing, has not created a climate change commission or advisory group and has no climate action plan completed or in progress (Pew Center on Global Climate Change 2009). However, the Comprehensive Master Development Plan for Georgia's coastal region peripherally references sea level rise and it recognizes that rising sea levels affect coastal development and destroy wetlands. At the local level, some municipal plans will incorporate climate change impacts into land management and protection plans "as tools become available" (City of Columbia 2008, 131).

Though Georgia does not have a climate action plan, the state enacted legislation in 2001 that requires all utilities, whether investor-owned or municipal, and electricity cooperatives to offer customers net metering. Photovoltaic (PV) systems, fuel cells, and wind turbines up to 10 kilowatts in capacity (for residential applications, or up to 100 for commercial purposes) are among the eligible technologies. In April 2008 Governor Sonny Perdue issued an executive order establishing energy efficiency programs and statewide coastal development plans. It directs state agencies to reduce energy consumption to a level 15 percent below what it was in 2007. Georgia also has a statewide net metering program that requires utilities to purchase excess power from customers who generate energy using systems for solar photovoltaic, fuel cell, and wind energy (DSIRE 2011).

Coastal region. Affiliated with the University of Georgia, the Georgia Sea Grant Program conducts research into shoreline change rates and coastal hazards on barrier islands, and the resulting data could influence adaptation strategies on the state's Atlantic islands. The program also manages the Governors' South Atlantic Alliance program, a regional agreement for coordinated coastal planning, which is discussed further in the "Interstate Coordination" section later in this chapter.

At the county level, in an effort to make it the "greenest county in Georgia," the Chatham County–Savannah Metropolitan Planning Commission funds the Chatham Environmental Forum. Focus areas for the forum include energy and climate change, as well as initiatives for sustainable transportation, green building, and GHG reduction. The forum also develops for the area climate change action plans, which are scheduled for completion in 2012. Despite the commission's effort to address climate change, the 2006 plan for Chatham County and Savannah makes no mention of rising sea levels or plans for either mitigating or adapting to climate effects.

Atlanta. Though Georgia lacks statewide and regional plans, Atlanta and some other cities have taken a leading role in climate change mitigation. In October 2006, Atlanta hosted the U.S. Conference of Mayors' second National Summit on Energy and the Environment, which focused on implementing a goal to make all new buildings carbon neutral by the year 2030. Two years later Atlanta created an Office of Sustainability with a goal of reducing the city government's carbon footprint by 7 percent by 2012. To reach this goal the city completed government building, lighting, and energy efficiency retrofits, while also passing a green-building ordinance that requires all new city construction and major renovations to be LEED-Silver certified.

In late 2010, the mayor's office put forth the City of Atlanta Sustainability Plan, which established multiple goals to address climate change as well as transportation, water conservation, air quality, green space, and local food systems. In developing this plan, the city conducted a sustainability inventory and researched best practices, which informed selection of future projects. Current projects include a residential energy efficiency rebate program, an alternative fuels plan, and an energy performance contract for city facilities. Among these projects is the proposed Community Climate Action Plan to be completed by 2012.

North Carolina

North Carolina formed a Climate Action Plan Advisory Group (CAPAG) to recommend to the governor and legislature specific policies focusing on reduction of GHG emissions through energy efficiency programs. The group's proposals also include a comprehensive list of state adaptation policies and preliminary recommendations addressing flooding; the forestry, fishing, and tourism industries; public health; and water supply and quality.

In 2007 Governor Mike Easley created a Renewable Energy and Energy Efficiency Portfolio Standard. Under this law, by 2021 electricity-producing public utilities must meet 12.5 percent of retail electricity demand through renewable energy or energy efficiency measures, and membership corporations and municipalities that sell electric power in the state would have to meet a standard of 10 percent by 2018. Renewable sources include solar, wind, and geothermal energy; hydropower; ocean current or wave energy; and biomass resources.

Other state actions relate to adaptation. The Coastal Management Program carried out by the North Carolina Coastal Resources Commission, for example, prohibits development of new houses in coastal areas that are likely to erode in the next 30 to 60 years. The state climate office is using weather modeling and monitoring to develop decision-support tools for the agriculture community. The National Centers for Coastal Ocean Science assist in a number of research projects to assess North Carolina's vulnerability to sea level rise. In one effort, researchers modeled different scenarios of sea level rise and inundation brought about by storms. These scenarios accounted for static sea level rise, tidal changes, winds (e.g., nor'easters), and hurricane storm surges (Center for Sponsored Coastal Ocean Research 2009).

Coastal region. The City of Greensboro signed the Mayors' Climate Protection Agreement in 2007, and the following year the city council created the Community Sustainability Council, an advisory group with a specific goal of reducing GHG emissions. The sustainability council took responsibility for the development of an energy efficiency and conservation strategy and a GHG action plan as well as implementation strategies. On January 4, 2011, the City of Greensboro accepted the council's sustainability action plan, which provides a GHG inventory and projections, a set of policies and strategies, along with methods for implementation. Policies set broad goals in eight topic areas that range from waste reduction to transportation and land use. To implement these goals, strategies provide methods that increase development densities, establish a sustainability account, develop green building standards, reduce solid waste in city operations, and promote urban agriculture.

Greensboro also hosts a number of green initiatives that do not address climate change mitigation directly, but have the effect of reducing greenhouse gases. Bike lanes and sidewalk construction projects encourage active modes of transportation with low emissions, while city buildings receive energy efficient enhancements like LED lighting, motion sensors, and Energy Star equipment and appliances. Additionally, the city's vehicle fleets are currently becoming less dependent on gasoline.

The Triangle. North Carolina has few regional or local planning efforts that address climate change adaptation, though some cities and counties pursue mitigation. Orange County joined ICLEI in 2003 and now takes part in its Cities for Climate Protection Campaign. The county, along with the cities of Chapel Hill and Carrboro and the town of Hillsborough, now leads efforts to inventory GHG emissions, identify reduction measures, and create a climate action plan.

Durham's Environmental Affairs Board, which is primarily a citizen advisory board, focuses on GHG emissions reduction. Working with Durham County and the metropolitan planning organization, it helped to create a greenhouse gas inventory and local action plan. The City of Durham itself adopted a GHG emissions reduction target in 2007, requiring by 2030 a 50 percent government reduction and 30 percent community reduction from 2005 baseline levels. The city hired a sustainability manager in 2008 to help implement the action plan.

Raleigh has signed on to the Mayors' Climate Protection Agreement, ICLEI, and the Sierra Club's Cool Cities Program. The city's comprehensive plan outlines 13 policy recommendations and 12 action items relating to energy security and climate change preparedness. These recommendations concern mitigation and cover a range of topics, such as incentives, retrofits, LEED buildings, renewable energy, and sustainable transportation.

South Carolina

South Carolina's state government formed the Climate, Energy and Commerce Advisory Committee in February 2007. The committee's final report, released in August 2008, focuses mainly on mitigation and also addresses adaptation and vulnerability to climate change (CECAC 2008). This report remains the primary statewide document guiding climate policy in South Carolina. The adaptation section encouraged the state to develop a climate, energy, and commerce action plan, and it contains the committee's analyses and recommendations to reduce GHG emissions and enhance energy and economic policy by 2020. The plan outlines 51 specific policy recommendations for climate change mitigation, such as incentives to promote recycling and improve design and construction of government buildings. Economic opportunities for renewable energy sources are also presented, along with recommendations for further assessment of adaptation strategies.

The state legislature has passed several laws relating to renewable energy, energy efficiency, and transportation. One of these acts provides biomass energy incentives by removing legislative caps on tax credits for equipment that produces biomass energy. A green building act requires appropriate standards for any state building of 10,000 square feet or larger. All state agencies are required to prepare energy conservation plans with a goal of reducing consumption by 20 percent below 2000 levels by 2020 (Pew Center on Global Climate Change 2009).

Coastal region. Citizen and nonprofit groups have developed policies to reduce the impact of climate change on specific coastal communities. Bluffton Township, a model coastal community, uses a transfer-of-development-rights tool to move growth away from sensitive shoreline (Coastal Conservation League 2009).

In 2005, the City of Charleston signed the Mayors' Climate Protection Agreement, committing the city to the initiative's 7 percent reduction in emissions by 2012. To reach this goal, Charleston seeks to create a more fuel-efficient vehicle fleet, retrofitting traffic and exit signs with LED lighting, and also retrofitting city buildings. To help implement climate mitigation strategies within its internal operations, the city also created a staff green team of more than 20 voting members from various departments.

The Charleston Green Committee (2010), a local citizen's group has prepared and submitted its climate action plan, the Charleston Green Draft Plan. With working committees focusing on transportation, buildings, land use and planning, and waste management and recycling, the group intends to reduce emissions and create sustainable development patterns. The plan was received as guidance by the city council, and the mayor and a rotating committee of council members will administer it.

Midland region. After signing the Mayors' Climate Protection Agreement in 2006, the City of Columbia created its Climate Protection Action Committee (CPAC), a volunteer citizen group charged with researching and providing recommendations on climate mitigation strategies. CPAC developed a 65 action-item climate action plan, and it also runs a voluntary green business program that provides Columbia businesses with advice and technical resources geared toward adopting green business practices. The city's 2008 comprehensive plan includes a few of CPAC's recommendations, such as a requirement for LEED-certified city buildings.

Interstate Coordination

While the strategies developed by the four states examined here seem to operate largely independently, a notable interstate effort seeks to coordinate regional decisions. The governors of Florida, Georgia, North Carolina, and South Carolina signed a partnership agreement in May 2009, which formed the Governors' South Atlantic Alliance. Its purpose is to identify regionwide research needs and build an action plan to address these needs. The alliance specifically addresses climate change, sea level rise, and increased storm intensity. Its recent actions have included forming focus groups and partnerships throughout the region that culminated in a final regional plan in conjunction with the South Atlantic Regional Research Plan.

In January 2011, the alliance released its final action plan, which the group will review every year at its annual meeting and update every five years. The technical teams for various issue areas will carry out the action plan through implementation procedures that address the specific details with a timeline for completion, which typically will be 12 to 18 months in duration. In this process, the executive and steering committees and the technical teams receive guidance and participation from supporting partners, such as federal agencies, nongovernmental organizations, academic institutions, and the private sector. While structured to create cooperation, membership in the alliance is voluntary and nonbinding. The effectiveness of this approach remains to be seen, as it has not been implemented yet. With further development and participation from each state and locality, however, the alliance may eventually provide a model regional framework.

Policy Implications

With impacts from climate change imminent, the coastal states of the Southeast recognize the need to carry out both mitigation and adaptation strategies. They approach development and implementation in three primary ways: by developing climate action plans, creating separate adaptation plans, or addressing issues as they arise without an overall plan (table 2.3). The states' efforts share a few general approaches. First, the city, region, or state forms an interdisciplinary climate action committee. Second, the committee quantifies expected

Table 2.3 Adoption of General Approaches to Climate Change

	Florida	Georgia	North Carolina	South Carolina
Climate action plan	Completed 2008 by Action Team on Energy and Climate Change		Completed 2007 by Climate Action Plan Advisory Group	Completed 2008 by South Carolina Climate, Energy, and Commerce Committee
Climate change adaptation plan	Completed 2007 by Florida Climate and Energy Commission			
No plan		No state level plan or advisory group		

Table 2.4 Implementation of Climate Change Strategies

	Florida	Georgia	North Carolina	South Carolina
Created a climate action committee	X		X	X
Determined specific impacts and effects for the region	X		X	X
Partnered with nearby states and localities	X	X	X	X
Created a climate mitigation plan	X		X	X
Created a climate adaptation plan	X			

impacts related to climate change. Finally, the committee creates a climate action plan for mitigating and adapting to change. Throughout this process, the climate action committee coordinates with government agencies at the local, regional or statewide levels (table 2.4).

The resulting plans set goals for reducing emissions and identify specific state, regional, and local strategies to address climate change. Objectives stem from these strategies, and those pursued by the southeastern coastal states include: incentives for renewable energy production and use, public utility mandates for renewable energy production, public building efficiency requirements, vehicle fleet efficiency standards, preparation for drought, and coastal development restrictions.

While these four states share some strategies, Florida's approach stands out, perhaps due to the state's extreme vulnerability to climate change and the consequences of the threats. Among them is increased drought, which affects water supplies, agriculture, and habitat while leading to more wildfires. Torrential rains will create more flooding, and higher temperatures and flooding may lead to insect infestation and insect-borne diseases. Additionally, bleaching of coral reefs and other adverse effects on marine life and fisheries may result from higher temperatures, and ecological changes will inevitably affect the Everglades and the state's other natural systems. Through comprehensive, integrated responses to these challenges, Florida has developed a model of mitigation and adaptation planning worth emulating by other states and jurisdictions in the southeastern region.

This overview of Florida's approach reveals a few key principles, some of which appear in local and metropolitan plans throughout the southeastern coastal states. As a suite of programs, these strategies represent the best in both individual requirements and comprehensiveness utilized in the southeastern coastal region. The key approaches pursued in Florida include: providing public education, regulating the built environment, protecting water supplies, prioritizing habitat and species protection, de-emphasizing technological solutions that impair ecological functions, requiring reviews by regional agencies and the state's attorney general, requiring sharing of feedback among regional and local agencies, mandating climate assessments, and ensuring short- and long-term funding for ongoing research and monitoring. Individually, these approaches may enhance climate change plans in a variety of other regions; as a combined program, they provide a model for the entire southeastern Atlantic coast.

The efforts of the Governors' Southeast Atlantic Alliance encompass the entire coastal region and offer the potential for greatly enhanced coordination of model programs on a broader regional scale. A key aspect of this approach involves clear and direct communication among executive leadership, planning committees, and those responsible for implementation, not to mention collaboration within and among the four states. Additionally, the alliance involves partners from other levels of government, the public and private sectors, and community groups. As such, this broad-scale partnership may prove pivotal for the entire coastal region in addressing climate change.

But a question clearly remains: Will the plans and strategies currently pursued in the southeastern states sufficiently counteract the intense climate change impacts expected in the region? Internationally, the favored approach focuses on overshooting expected impacts by preparing for the worst. To achieve this level of preparation, the region must expand its programs rapidly and coordinate the very best of the local, state, and regional efforts now underway.

Future Directions

The expected impacts of climate change will likely require the southeastern coastal states to adopt a more organized regional approach. Many existing efforts set ambitious goals and identify best practices, but they are localized to a single city or state and lack tangible, cooperative strategies for regional implementation. The sole existing regional body—the Governors' South Atlantic Alliance—addresses the effects of climate change on coastal and oceanic systems, but it functions in a research capacity rather than as a policy-focused organization. Its recently completed action plan both identifies the need to assess the impacts of climate change and outlines goals to conduct numerous long-term vulnerability studies, but it expresses little interest in mitigating these impacts.

As the only regional entity operating in an area of the United States that is predicted to be among the hardest hit by climate change, the alliance should have a greater leadership role in creating sustainable policies among all 12 southeastern states, or a new regional body should be assembled. For direction, these states can look to other regions of the country that are leading the way in climate change adaptation and mitigation. A 12-state Southeast initiative modeled on existing efforts would set mitigation and adaptation goals and provide policy direction to accomplish them. This initiative could utilize best practices emerging from such regional initiatives, such as the establishment of a regional cap-and-trade program.

U.S. Regional Initiatives

Existing initiatives in the West, Midwest, and Northeast provide examples for the Southeast. More ambitious collaborative actions, policy directions, and mitigation efforts are now underway in all three regions, including the Western Climate Initiative (WCI), the Western Governor's Association (WGA) Adaptation Plan, the Midwest Energy Security and Climate Stewardship Platform from the Midwest Governor's Association (MGA), and both the Regional Greenhouse Gas Initiative (RGGI) and the Transportation and Climate Initiative (TCI) in the northeastern and Mid-Atlantic states.

The WCI includes 12 U.S. states, five Canadian provinces, and five Mexican states. Its main focus is a regional cap-and-trade program to reduce GHG emissions 15 percent below 2005 levels by 2020. The initiative requires the partners to set an overall regional goal to reduce emissions; develop a market-based, multi-sector program to achieve that goal; and participate in a GHG registry. The first phase of the plan is to be implemented in 2012 and then followed by a cap on emissions in 2015.

In 2009 the WGA recognized the need for collaboration, when it began compiling its adaptation plan. WGA is organized similarly to the Governors' South Atlantic Alliance, but includes a larger region and a close focus on climate change issues. Through a work group of western-state experts, WGA created a report of climate change adaptation strategies tailored to the region. The original work group continues to review climate change legislation and resulting impacts on the region as well as conducting further modeling research.

Member states of the MGA released in 2007 its Midwest Energy Security and Climate Stewardship Platform, which outlines several goals and policy options for the participating states. The platform highlights the region's growing biofuels industry, energy efficiency potential, prospects for underground storage of captured carbon, considerable wind power potential, and manufacturing capabilities. The current focus is on a GHG reduction proposal that will establish a cap-and-trade program.

The RGGI includes 10 northeastern and Mid-Atlantic states and focuses on implementing a cap-and-trade program to reduce the CO_2 emitted from regional power plants. RGGI capped these emissions, while allowing sources to trade emissions allowances at quarterly auctions. The program began in 2009 by capping emissions at then-current levels, but its goal is to reduce emissions 10 percent by 2018.

Formed more recently, in 2010, the TCI focuses on expanding transportation options and mitigating the transportation sector's effect on climate change, public health, and air quality. This initiative was formed by environment, transportation, and energy agencies in the northeastern and Mid-Atlantic states, rather than by their governors. These agencies will establish and fund the Transportation, Energy, and Environment Staff Working Group, which will direct the initiative's planning and will seek public and private funding for projects.

Regional Best Practices

As the only area in the United States that does not have a regional initiative addressing climate change, the Southeast has the opportunity to learn from the established programs that outline a number of effective practices for setting and achieving regional goals, several of which are described below.

Committees and work groups. Each initiative's action committees and task forces help implement developed policies. The WCI, for example, designates committee members from each of its member states and provinces to design emissions reductions policies. Designated task force members then implement the established goals. To facilitate further collaboration with regional initiatives beyond its membership, WCI selected two representatives to work as liaisons with other states and regional initiatives. Using a similar model to focus on expanding regional transportation options, the TCI engages 90 policy makers. State-based representatives facilitate a master plan for regulating fuels and transportation, then each state takes responsibility for implementation within its purview.

Membership levels. Both the WCI and the Midwestern Greenhouse Gas Reduction Accord designate state members to be partners or observers. Partner states are responsible for leading the organization and making final decisions, designating their representatives, and participating in working committees. Observer states are welcome to participate in the working committees, but are not responsible for final decisions. Observer states often become partner states after a period of time.

Regional emissions targets. Most of the existing regional initiatives set emissions targets and then use action plans and committees to reach them. The WCI aims to reduce GHG emissions to 15 percent below 2005 levels by 2025, and members of the Midwestern Greenhouse Gas Reduction Accord have agreed to a reduction target of 60 to 80 percent below 2010 emissions levels. The New England Governors/Eastern Canadian Premiers Climate Change Action Plan, a parallel effort to the RGGI, calls for reducing GHG emissions to 10 percent below 1990 levels by 2020.

Transportation fuels. The transportation sector is responsible for around 30 percent of GHG emissions. On this basis, most regional agencies include transportation and fuels associated with it in their goals and action plans. In 2008 the WGA developed a plan and adopted policies for advancing alternative transportation fuels in the western United States. While the plan's principal impetus is to address concerns of oil shortages, price spikes, and national security, the governors of the member states believe alternative fuels also can reduce global warming impacts from transportation.

In 2009, over objections from the oil industry, governors in the RGGI's participant states and Pennsylvania signed an agreement to develop low-carbon fuel standards, with the aim of reducing GHG emissions from cars and trucks. MGA established an advisory group in 2010 to make biofuels sourced in the Midwest competitive with fuel standards in other states and regions of the United States. The governor-appointed group members included a geographical cross-section of regional stakeholders whose experience brings to bear work in agriculture, government, industry, and nongovernmental organizations.

Cap-and-trade. Three regional initiatives in the United States have developed cap-and-trade program plans. Such a program sets an overall emissions cap while allowing companies to trade emissions allowances. They thus achieve cost-effective reductions. States that are members of the MGA account for 14 percent of total U.S. GHG emissions, and are still in the process of developing their cap-and-trade program. The WCI recently released recommendations for design of a cap-and-trade program for its constituent states, while the RGGI is already implementing its own cap-and-trade program aimed at regional power plants.

Trading emission allowances keeps costs low because the method provides flexibility in how and when reductions are made. For example, entities that reduce their emissions below the number of allowances they hold can sell excess allowances or bank them for later use. Selling excess allowances to another entity allows the seller to recoup some of its emissions-reduction costs, and banking allowances lessens future compliance costs.

The RGGI was the first mandatory, market-based CO_2 emissions reduction program in the country. It sets a cap on carbon dioxide emissions from power plants and allows sources to trade emissions allowances at quarterly auctions. This program began by capping emissions at current levels in 2009, and by 2018 it will have been responsible for 10 percent emissions reduction. States sell nearly all emission allowances through auctions and invest proceeds in consumer benefits such as energy efficiency, renewable energy, and other clean energy technologies, thus increasing the clean energy economy and creating green jobs in each state.

Southeastern Regional Climate Initiative

Many of the southeastern states already are working toward achieving ambitious mitigation and adaptation goals, but a stronger regional body is required in order to use existing state and local adaptation and mitigation efforts to form cohesive goals for the region as a whole. For such an organization, states could choose whether to start as partners or observers, with the partners working closely with one another to develop an action plan and implementation steps that will achieve the outlined tasks. Nine general priorities, which are based on this chapter's review of climate plans in the southeastern coastal states, should be reflected in an interregional compact (table 2.5).

Several current conditions make the Southeast region suitable for a cap-and-trade scheme. Among the four coastal states, more than 179 coal-fired generating stations are in operation. North Carolina produces a disproportionately large amount of CO_2 and ranks fourteenth in the nation, only slightly behind California, a state with a population that is four times larger (Source Watch 2010). The cap-and-trade program already in effect in the Northeast provides a model for the Southeast, and in the future a larger regional cap-and-trade program could connect the entire East Coast in a manner similar to initiatives such as the WCI and RGGI.

Table 2.5 Climate Change Priorities and Strategies for the Southeastern Coastal States

Priority	Suggested Strategies	Exemplary Locales
1. Reduce GHG emissions Possible methods include: • improve energy efficiency • increase renewable energy production • improve waste management and recycling operations • reduce automobile dependence • improve the efficiency of land use	Address energy efficiency in government operations through ordinances and educational programs	Florida, Georgia, South Carolina, and North Carolina Miami and Orlando (FL) Atlanta (GA) Greensboro and Raleigh-Durham (NC) Charleston and Columbia (SC)
2. Set specific, challenging, measurable targets for both emissions and energy consumption reductions	Ongoing annual environmental scorecards and assessment programs	Florida, Georgia, and North Carolina Miami and Orlando (FL) Atlanta (GA) Greensboro and Raleigh-Durham (NC) Charleston and Columbia (SC)
3. Embrace innovative strategies to reduce energy consumption	Institute net metering to encourage renewable energy production by individuals; offer training in design standards (e.g., LEED-NC)	Florida, Georgia, and North Carolina Miami and Orlando (FL) Atlanta (GA) Greensboro and Raleigh-Durham (NC) Charleston and Columbia (SC)
4. Restrict development in hazardous and fragile shoreline areas that are likely to erode	Coastal management plans; and transfer of development rights programs	Florida, Georgia, and North Carolina Chatham County (NC)
5. Convene climate science research framework	Include agenda and institute funded advisory council	Florida and Georgia
6. Protect ecosystems and biodiversity in terrestrial, freshwater, and marine habitats	Prioritize preservation of vulnerable species; utilize the transfer of development rights to preserve sensitive shoreline	Florida, Georgia, and South Carolina
7. Reduce dependence on bulk hardening to stabilize shorelines (Exception: specifically defined conditions that require emergency beach stabilization)	Prioritize coastal wetland preservation to create buffering from storm surges	Florida and Georgia
8. Enhance new buildings and developments to withstand potential storm loads	Require new buildings and development to meet design criteria for specific storm surge conditions	Florida
9. Promote financial incentives for biofuels; develop standards for renewable fuel		Florida

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Figure 3.1 New Orleans

Source: Weiss and Overpeck, University of Arizona.

dark blue overlay areas = low-lying coastal areas of ≤ one meter elevation vulnerable to future sea-level rise

Chapter 3

New Orleans

Douglas J. Meffert and Joshua A. Lewis

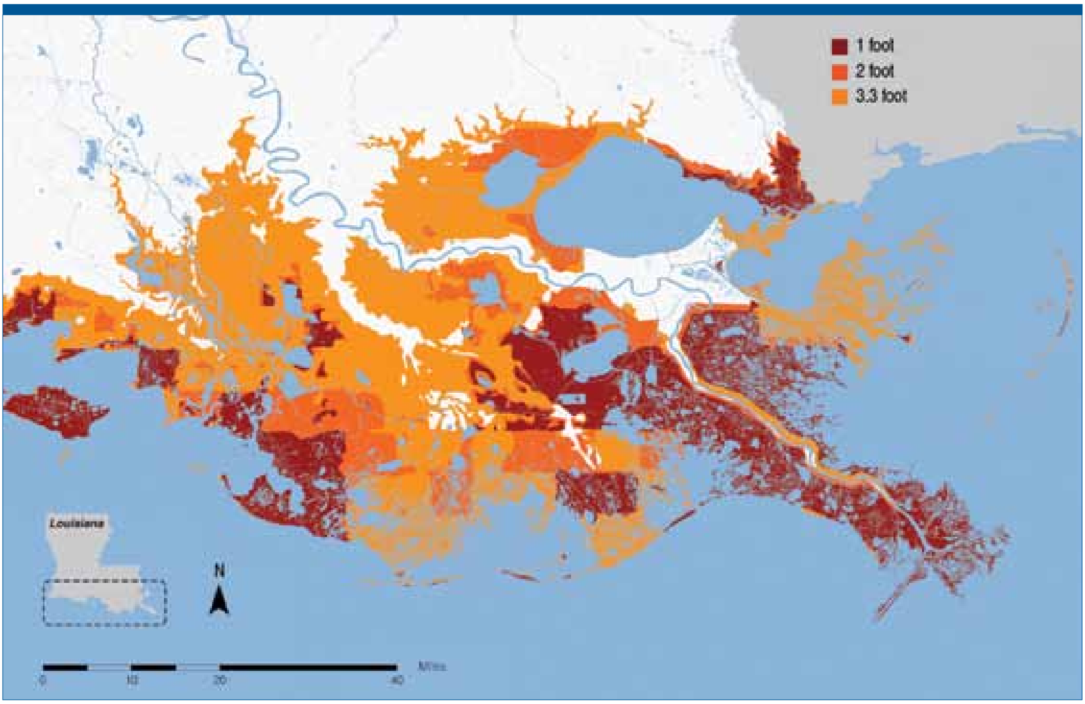
For centuries historic port cities built on river deltas have had to deal with the dynamic nature of river and estuarine systems and related periodic flooding. Yet their strategic locations for waterborne commerce and their wealth of natural resources maintain their role as regional economic engines despite the vulnerabilities they face due to climate change. New Orleans, in particular, represents an instructive "urban laboratory" in which to examine climate change adaptation and mitigation: In addition to having among the world's highest rates of coastal erosion and relative sea level rise, the city experienced a systemic shock to its entire urban infrastructure in August 2005 when Hurricane Katrina struck (figure 3.1). While the prolonged flooding that resulted presented many challenges to recovering the city's natural and built environment and community services, the hurricane also created an opportunity for innovation in metropolitan planning on a scale unprecedented in recent U.S. history.

The climate change–related sea level rise, which is expected to range from 3 to 10 millimeters (mm) per year over the next 50 years in coastal Louisiana, exacerbates the susceptibility of the New Orleans metropolitan area and the rest of coastal Louisiana (Tornqvist et al. 2008). When one takes into account both the subsidence endemic to Louisiana's deltaic coast and the global sea level rise, recent estimates of relative sea level rise estimate the Gulf of Mexico could increase by 0.6 to more than 2 meters (m) over the next century (Day and Giosan 2008; Young and Pilkey 2010). This rate of relative sea level rise is the highest in the United States. Figure 3.2 illustrates several possible impacts of sea level rise projections, which range from approximately one to three feet.

Although relative sea level rise and potential increased intensity of hurricanes and flooding events are the primary contributors to the increased vulnerability of New Orleans and coastal Louisiana, the region faces other projected climate changes as well. Historically, Louisiana's climate has been variable, although climate change could exacerbate or shift this variability with some estimates projecting increases of up to 10°F for winter low temperatures and as much as 7°F for summer high temperatures. Although extreme rainfall events increased in Louisiana throughout the twentieth century, overall rainfall, which averages between 40 and 70 inches annually, is likely to decrease in coastal

Figure 3.2 Comparison of Current Coastline of Louisiana Delta with Predictions for Sea Level Rise by 2100

Source: Jonathan Tate



Louisiana through the twenty-first century and could create additional stress to coastal wetland habitats.

Despite these recent events and dire predictions, urban and rural populations in Louisiana's coastal zone have long coexisted with the region's natural flooding propensity. In particular, many small towns in the deltaic plain prioritize residential land use along the limited levee areas of bayous and former distributaries of the Mississippi River in order to remain above sea level and minimize risks associated with flooding and storm surge. During this century, however, many communities that heretofore have been able to sustain themselves near sea level will succumb to sea level rise while those on the ridges of the former Mississippi River distributaries that remain above sea level will no longer have the wetland buffers that historically have protected them from diurnal sea level fluctuations, intermittent storms, and less frequent but increasingly catastrophic hurricane and tropical storm surges.

For many of these towns, residential relocations are inevitable. The BP Deepwater Horizon oil release in 2010 worsened this situation and may compound the damages to wetlands in yet unforeseen ways. Moreover, given the need for some relocations, the State of Louisiana has an opportunity to reexamine its future land use priorities in the delta plain and implement both structural and nonstructural interventions that will maximize the inherent economic productivity of these systems while minimizing economic and cultural losses and social justice dilemmas.

Both the prevailing gradual environmental trends (e.g., relative sea level rise and coastal wetland loss) and acute threats (hurricanes and flooding) increase the vulnerability of the New Orleans metropolitan region. The pre-Katrina trend was already one of dramatic historical wetland loss because the marsh habitats, vestiges of former Mississippi River delta lobes, are subject to natural compaction and deterioration. This tendency, however, is exacerbated by relative sea level rise and other anthropogenic interventions, among them building up levees along the Mississippi River, oil and gas exploration, and wetland conversions to agriculture.

Current plans include restoration of as much of this marsh as quickly as possible, primarily through adaptation measures including restoration of natural delta building, marsh creation from use of dredged material, water control structures, and such hard structures as dikes and levees (CPRA 2007; LRA 2007). Because the most interior marshes provide particular ecological services as well as storm surge protection to more densely populated areas, including New Orleans, they have received conservation and restoration prioritization. The most prominent feature of occupied landscape currently identified for abandonment is the modern ("bird's foot") delta of the Mississippi River. Some plans call for ultimately utilizing this alluvial material for restoration of marshlands located proximate to more densely populated areas.

While a larger regional levee system in South Louisiana is proposed to provide 100-year protection for about 120,000 rural residents in coastal areas, thousands of others remain outside of the reach of planned protection systems (Walsh 2007). People living in the delta lobe (e.g., Boothville-Venice), for example, must face the ultimate abandonment of these lands to accommodate marsh creation through the beneficial use of dredge material that has been prioritized particularly for presently degraded marsh in Barataria, Terrebonne, and Breton Sound basins. So far, relocation is based primarily on residents' voluntary actions. During the next several decades, larger towns inside existing and proposed protection systems and cities such as New Orleans and Louisiana's capital, Baton Rouge, will likely serve as population clusters for people seeking higher ground.

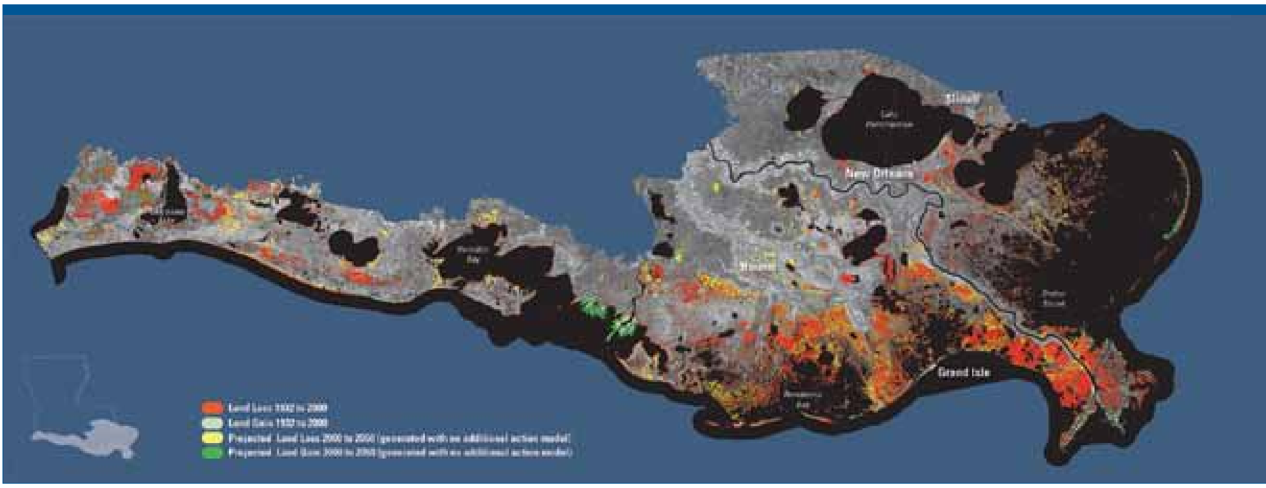
Historical and Geological Background

Creation and Loss Along Louisiana's Coast

Louisiana's coastal zone was formed from sediments deposited as the result of a series of 16 major Mississippi River deltaic episodes over the past 7,000 years, which created a region of coastal wetlands that covers 3.3 million acres of the state (Cowan and Turner 1988; Good et al. 1995; Turner and Rao 1990). Over the last 200 years, however, wetlands in the United States have

Figure 3.3 Existing and Projected Coastal Wetland Loss and Land Gain in Louisiana

Source: Barras et al. (2003)



been drained, dredged, filled, leveled, and flooded for urban, agricultural, and residential development. Since 1930 Louisiana alone has lost 2,300 square miles of coastal wetlands—the highest such rate of loss, not only in the United States, but throughout the world (CPRA 2010). Although these coastal wetlands represent 30 percent of those in the contiguous United States, they are experiencing 90 percent of the country's coastal wetland loss overall (CPRA 2007; Dahl 2000) (figure 3.3). The causes include cumulative natural and human-induced impacts.

Beginning in the eighteenth century and accelerating after the record flood in 1927, the construction of artificial levee systems has eliminated the overbank sediment contributions of flood flows from the Mississippi River to southeastern Louisiana (Kesel 1989; Turner and Rao 1990). In addition, during the past two centuries, dredging navigation channels, oil and gas exploration and production, land reclamation, the construction of commercial and industrial facilities, and the fur industry's introduction of invasive nutria species into the habitat, have all further damaged the coastal region in terms of primary and secondary wetland losses. These activities have reduced new accretion, lessened freshwater inflow, increased saltwater intrusion and wave energies on fragile interior marsh substrate, and destroyed emergent vegetation that otherwise would bind sediments and produce organic matter.

Extrapolating from the current rate of land loss, by the year 2050 Louisiana will have lost more than one million acres of coastal wetlands, an area larger than the state of Delaware (Meffert et al. 1997). By 2050, the Gulf of Mexico will continue to advance as far as 33 miles inland, transforming previously productive wetlands into open water and leaving major towns and cities, such as New Orleans and Houma, exposed to open marine forces of the Gulf of Mexico (CPRA 2007).

The combined effects of dredging the Mississippi River Gulf Outlet, subsequent wave energies and saltwater intrusion, and decreased freshwater and sediment supply from the Mississippi River have degraded the marsh in Breton Sound. Before its closure, protection efforts included a combination of breakwaters and shoreline rock barriers.
Photograph © Douglas Meffert.

As this coastal land-loss trend continues, Louisiana also is sustaining major economic and social losses, including damages, control costs, and insurance claims from floods and hurricanes. Among the sectors and operations affected are oil and gas infrastructure; private land and residences; commercial seafood production; commercial hunting and trapping; recreational hunting and fishing; shipping; channel and river maintenance; drinking water; water quality improvements; and employment. According to an estimate compiled by the Louisiana Coastal Wetlands Conservation and Restoration Task Force (LCWCRTF 1993), when functional values and those of roads, waterways, and oil and gas infrastructure are considered alongside biologic productivity, the value of Louisiana's coastal wetlands exceeds $100 billion. These resources provide the largest fishery landing in the lower 48 states, the country's largest fur harvest, 21 percent of its natural gas supply, and protection for waterborne cargoes that represent 25 percent of the nation's total exported commodities (CPRA 2007). Since many of these benefits and services are of national importance, the entire United States, not just Louisiana, stands to lose a vast economic resource.

New Orleans: An Urban System in a Wetland Ecosystem Context

Paradoxically, for most of the twentieth century New Orleans was sustained by enhanced drainage of its delta subsurface along with increased efforts to manage land and water (e.g., with levees and floodwalls) at the city's perimeter and regional environs. U.S. Census Bureau estimates indicate, however, that New Orleans' population reached its peak of 627,585 residents living on 36.8 square miles in 1960 and declined to 484,674 living on 66.7 square miles by 2000. Those who remained in the metropolitan region during this period often moved to low-lying suburban parishes and, among those who continued to live in Orleans Parish, many moved to new low-lying areas of reclaimed wetlands that had been drained to accommodate suburban-style development within the parish's incorporated area. Decreased population combined with almost doubling the city's developed footprint resulted in a reduction of more than 50 percent in population density. Measured as population divided by occupied area (excluding parks, fields, forests, wetlands, water bodies, etc.), the city's density declined from 17,053 residents per square mile in 1960 to 7,266 in 2000 (Campanella 2007). During this same period, coastal Louisiana was experiencing one of the highest coastal wetland loss rates in the world.

The long-term viability of New Orleans depends on restoring its coast on an unprecedented scale, which will be phenomenally expensive. Estimated costs associated with maintaining and restoring Louisiana's coastal wetlands are in the tens of billions of dollars. While such restoration occurred on a very small scale prior to 1990, larger-scale efforts were not employed until 1990, when Senators John Breaux and J. Bennett Johnson enabled passage of the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA). That legislation led to an influx of state and federal funding of approximately $50 million per year that was intended for Louisiana coastal wetlands restoration projects. In the late 1990s, the continued loss of wetlands and increased vulnerability of New Orleans was widely discussed and debated among scientists, engineers, and policy makers.

During the twentieth century hope was widespread that it was still possible to restore and retain the historic wetland footprint of coastal Louisiana. Over the past 10 years, however, the impacts of Hurricanes Katrina and Rita and the mounting body of research regarding Louisiana's vulnerability to sea level rise is creating a greater consensus that a sustainable Louisiana coast will be considerably smaller than it has been historically.

Post-Katrina Opportunities for Restoration

Early in the twenty-first century, additional funding streams for coastal restoration were developed, including the Coastal Impact Assistance to States Program (CIAP) established by the Energy Policy Act of 2005 and the Louisiana Coastal Area (LCA) program, which authorized approximately $2 billion for 15 small- to large-scale projects through the U.S. Water Resources Development Act of 2007. The immensity of the wetland loss problem, however, and the unlikelihood of re-establishing this historical coastal footprint was launched into the general public consciousness in 2005, when Hurricanes Katrina and Rita resulted in the conversion (loss) of approximately 217 square miles of wetland to water statewide (CPRA 2007). Around metropolitan New Orleans, where the wetlands historically formed a critical storm surge buffer, the loss of coastal marshes during that year greatly exacerbated the city's future vulnerability to storms.

While Louisiana's current coastal restoration efforts are funded by a variety of state and federal sources, the additional billions of dollars needed

Degraded cypress tupelo swamp in the Bayou Bienvenue wetland area adjacent to New Orleans and its Lower Ninth Ward
Photograph © Joshua A. Lewis.

for large-scale coastal renewal depend largely on the Gulf of Mexico Energy Security Act (GOMESA) championed by Louisiana's Senator Mary Landrieu and former Senator Pete Domenici of New Mexico and passed by Congress in December 2006. Through GOMESA, the four oil and gas producing states bordering the Gulf of Mexico (Alabama, Louisiana, Mississippi, and Texas) began in 2007 to receive dedicated funds from federal oil and gas leases explicitly to support coastal conservation, restoration, and hurricane protection. Starting in 2017, these funds could amount to hundreds of millions of dollars annually. It is ironic that Louisiana depends on nonrenewable fossil fuels for restoring its coast, and it is these same energy sources that emit the greenhouse gases (GHG), such as carbon dioxide, that exacerbate vulnerability from sea level rise and more intense hurricanes powered by warmer gulf waters.

The BP Deepwater Horizon oil spill in 2010 illustrates issues regarding wetlands protection and increases the tension between the environmental sustainability of Louisiana's coast and the region's primary economic sectors, including oil and gas exploration and fisheries. Senator Landrieu convened a coalition of experts, whose recommendations were presented to an interagency working group established by President Barack Obama's Council on Environmental Quality. The result could be a new Congressionally authorized entity, perhaps analogous to the Tennessee Valley Authority or the Denali Commission, that would govern and implement a coordinated coast-wide restoration, protection, and water management plan.

The proposal for a new authority would consolidate and reform existing state and federal coastal restoration, shipping, and flood control programs and transfer to a new agency all of these responsibilities, many of which presently are overseen by the Army Corps of Engineers. This agency would assume control of the majority of the civil works budget of the New Orleans District of the Army Corps of Engineers along with other relevant programs administered by disparate federal agencies, including the Departments of the Interior, Agriculture, and Commerce. The efforts to establish this new authority, along with draft legislation proposed to Congress, seek to accelerate the timetable for revenue sharing established by GOMESA to generate as much as $1 billion annually to support long-term coastal restoration.

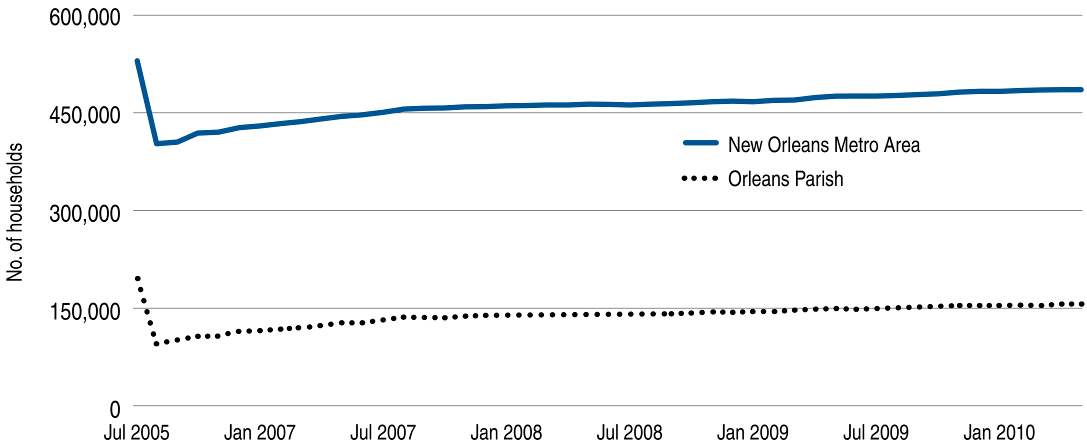
Following the BP Deepwater Horizon oil spill, President Obama appointed Navy Secretary Ray Mabus to oversee long-term restoration along the Gulf Coast. In addition to examining the proposed new authority described above, Secretary Mabus established a complementary energy-transition initiative to ensure that investments in renewable energy research and technology development would help ensure environmentally benign energy generation for the nation's long-term needs. At the same time, it is recognized that continued dependence on oil and gas is important for near-term energy demands and revenue generation for coastal restoration. Renewable energy investments focused on Louisiana's natural renewable resources (e.g., hydrokinetic energy in the Mississippi River, biofuels from agriculture and wind energy from oil rig platform networks) would help secure additional economic gain and offer the region an opportunity for climate change mitigation.

New Orleans Metropolitan Area Institutional Planning

Since Hurricane Katrina, much has been written and debated about how and where in New Orleans its displaced residents should live. Many of these opinions and recommendations suggest rebuilding—or relocating—with the expectation of future flooding, which would result in clustering populations in the areas deemed safest from natural disaster and enhancing natural processes to the greatest extent possible. Since Hurricane Katrina, New Orleans' residential population has rebounded from a low of 70,000 residents in October 2005 (based on U.S. Postal Service estimates) to 343,829 in 2010 (based on 2010 census data). According to the Greater New Orleans Community Data Center (GNOCDC) analysis of U.S. Postal Service delivery statistics, the number of households receiving mail in Orleans Parish and New Orleans metropolitan area reached 164,337 and 493,087, respectively, as of December 2010 (figure 3.4).

Figure 3.4 Households Receiving Mail in the New Orleans Metropolitan Area, July 2005–February 2010

Source: Greater New Orleans Community Data Center.



Note: New Orleans metropolitan area includes the parishes of Orleans, Jefferson, Plaquemines, St. Bernard, St. Charles, St. John the Baptist, and St. Tammany. For more information on using U.S. Postal Service Delivery Statistics to track the repopulation of New Orleans and the metropolitan area, contact the Greater New Orleans Community Data Center.

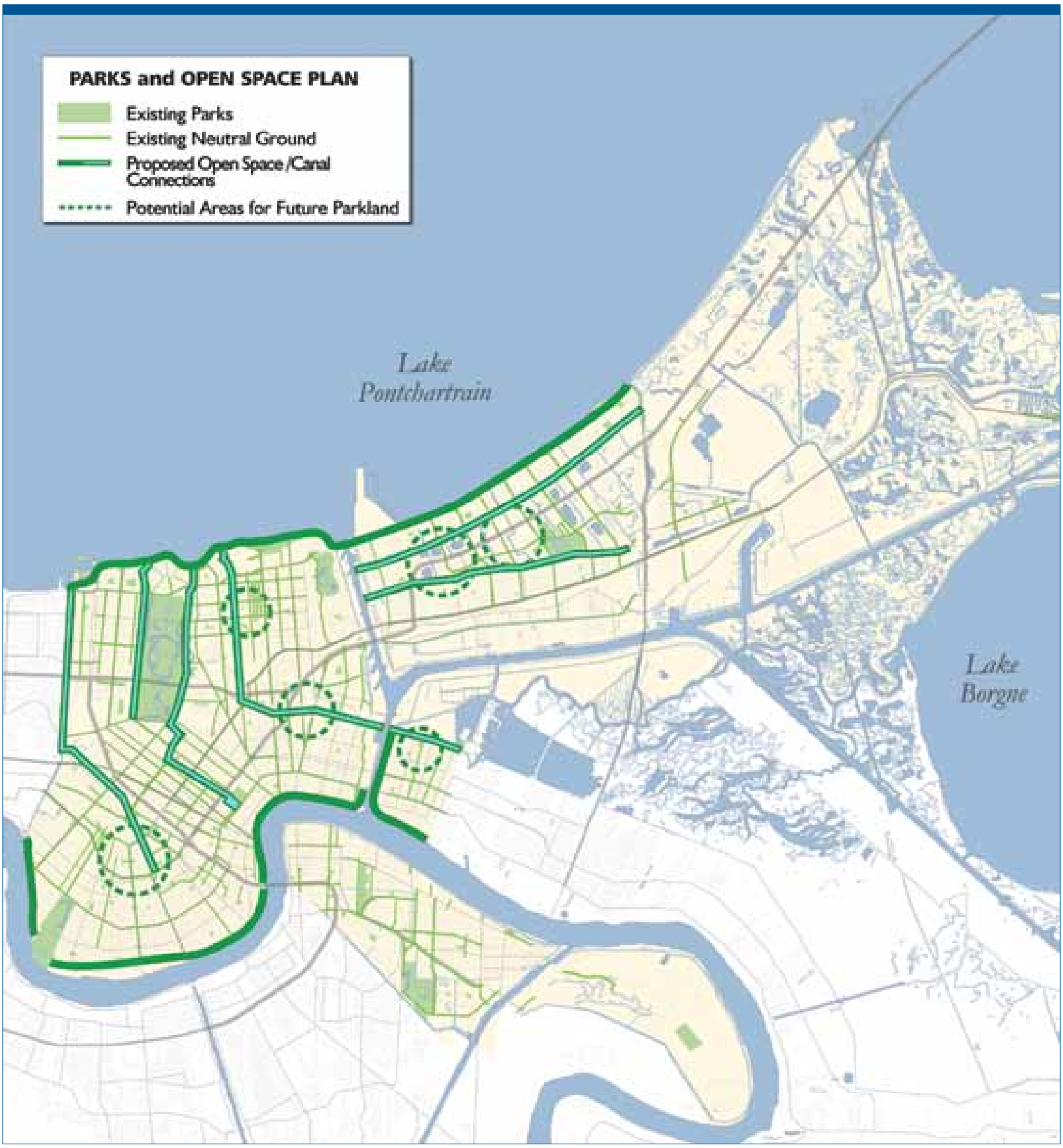
To address the changing needs of the city and its residents, five overarching, sometimes conflicting, planning processes have been established in recent years.

Bring New Orleans Back Commission

Less than two months after Hurricane Katrina made landfall, the Bring New Orleans Back Commission (BNOBC) became the first major post-disaster planning initiative. While the BNOBC action plan did not address climate change explicitly, it included a general recommendation for converting low-lying areas into greenspace through market-based buyouts that offered residents of those areas the chance to relocate to higher ground that is less prone to flooding. However, the commission's message and the now-infamous "green dot map" (figure 3.5) that accompanied it were delivered before sufficient work on community engagement was complete and, since no financial mechanism was in place to guarantee compensation, the BNOBC suffered significant rejection from politicians and neighborhoods alike.

Ultimately, recommendations from the various BNOBC committees were presented publicly and accepted by then-mayor C. Ray Nagin. The mayor issued a final report, *Rebuilding New Orleans*, which summarized these recommendations six months after the commission was formed, but a lack of continued funding effectively prevented their implementation (Nagin et al. 2006). This report made no mention of climate change, but it did endorse adaptation measures, including enhancement of local and regional flood protection efforts,

Figure 3.5 New Orleans Parks and Open Space Plan, with Potential Areas for Parkland Indicated
Source: Prepared by WRT (Wallace Roberts & Todd design firm) for BNOBC.



Note: Presented to the general public by the BNOBC Urban Planning Committee, 11 January 2006.

that would return these protection systems to their original designs (protection from a 1-in-100-year flooding event) and regional wetland restoration to reduce storm surge, which was to be funded by oil and gas production revenues.

Two City Plans

The subsequent city council effort, the New Orleans Neighborhoods Rebuilding Plan (NONRP), led by Lambert Group, abandoned any suggestion of specific locations of open parkland in damaged, low-lying areas, although increasing residential density was encouraged for sections of town less prone to flooding (Fields 2009). This plan focused only on the areas that had flooded due to Hurricane Katrina, however, so it was not a systemic citywide plan. This effort then prompted development of the Unified New Orleans Plan (UNOP), which had the goals of expanding the planning scope to include the entire city and to synthesize into a unified report the recommendations from BNOBC, NONRP, and other emerging neighborhood-based plans. While UNOP supported so-called sustainable projects, generally it was not confined to the availability of financial resources or the realities of likely residential populations in the city's various districts. The plan has been viewed as an ideal wish list of each district's desired projects, and neighborhoods are now re-examining the plan in terms of likely and practical investments.

To facilitate funding and implementation of community-supported projects outlined in NONRP and UNOP, the City of New Orleans formed a new Office of Recovery Management (ORM), which later evolved into the Office of Recovery and Development Administration (ORDA). As such, it oversaw aspects of recovery as well as city planning, safety, and permits. Given that the city had already endorsed repopulation throughout the entire pre-Katrina footprint (through the NONRP and UNOP processes), ORDA identified 17 zones for targeted investments (ORM 2007). The selection basis for these zones centered on clusters in which limited rebuilding dollars could achieve the greatest impact in both areas severely damaged by flooding (e.g., the Lower Ninth Ward and New Orleans East) as well as less-heavily damaged areas. The funding ORDA anticipated to facilitate these investments was identified as a combination of traditional community development block grants (CDBGs), disaster-CDBG supplements through the Louisiana Recovery Authority, Federal Emergency Management Agency (FEMA) public assistance grants, hazard mitigation grants, city bonds (including "blight bonds"), and other sources. Although ORDA did not endorse a smaller city footprint, it did promote voluntary land swaps by which homeowners in low-lying areas could exchange their property for lots in higher, less flood-prone parts of the city.

New Orleans Master Plan and Comprehensive Zoning Ordinance

In 2008 Goody Clancy, an architecture and urban design firm based in Boston, Massachusetts, was hired by the City of New Orleans to develop a draft master plan and a comprehensive zoning ordinance that, if adopted, would have the force of law. In Orleans Parish this planning process is dedicated to providing recommendations for built and natural habitats that will be sustainable within the parish boundaries, with the recognition that jurisdictional oversight would exist only within the incorporated boundary of Orleans Parish. The highest priority for infrastructure is a systemic plan and agency coordination and investments that will improve resistance to floods and hurricanes (table 3.1).

Table 3.1 Guiding Principles and Key Features of the Draft New Orleans Master Plan
Source: Goody Clancy

Guiding Principles	Master Plan Key Features
• New Orleans' future must be shaped by an honestly optimistic assessment of risks and opportunities. • Geography and water shape value and culture as well as drive risk. • New Orleans cannot survive as a viable community if it must evacuate frequently. • A 1-in-100-year flood protection level, while essential, is not adequate; it is less than the city and the nation were committed to prior to Hurricane Katrina. • The levees, pumps, and wetlands the city currently relies on are all that can be expected for the foreseeable future. • The state's and the Army Corps of Engineers' master plans are not substitutes for effective action at the city level because the authorization, funding, and construction process for bold and effective action on next-generation storm protection, coastal restoration, and climate change will be measured in decades. The city does not have this time. • The ways New Orleans chooses to live with its levees, pumps, and wetlands can increase its near-term protection and resilience. • Although risks are not uniform across the city, no part of it is immune from risk. Plan *for* water, not against it. • No part of the city should be left out of its recovery and redevelopment, but the timing and nature of recovery and redevelopment will and does vary. • It is not possible to immunize the city from risk; we must make it resilient to risk.	• A 1-in-500-year minimum level of protection from storms • A city that has to evacuate only under extraordinary circumstances • A city planning for both current *and* future risks—specifically those associated with rising seas • A city that views water as an asset • Land use and water management practices that reduce risk, enhance land values, and increase resilience to water, storms, and other environmental hazards • Plan for and reduce subsidence at the city level • Plan for and manage interior hydrology and stormwater to reduce flooding risk • Encourage regional cooperation and planning • Support and advocate for improvements to long-range storm protection system • Support and advocate for coastal conservation and restoration at state and federal levels • Support and advocate for effective responses to rising seas and climate change • Encourage residents to "build smart" • Harden essential infrastructure against risks of wind and water • Community involvement—shared responsibility, collective benefit • Develop "smart evacuation" options (e.g., choose locations within a community when appropriate) and accommodate evacuees when they return

This planning process also established a Sustainable Systems Working Group (SSWG) with a research and community outreach process that was completed late in 2009. Sustainable recommendations in the master plan contained climate change adaptation and mitigation measures related to the following elements:

1. Community facilities and services
   a. Major components of nontransportation-related infrastructure, including water and sewer, electric, gas, and waste disposal

b. Location, typology, and characteristics of key community facilities, including schools, libraries, community centers, health clinics, police, fire, courts, and criminal justices

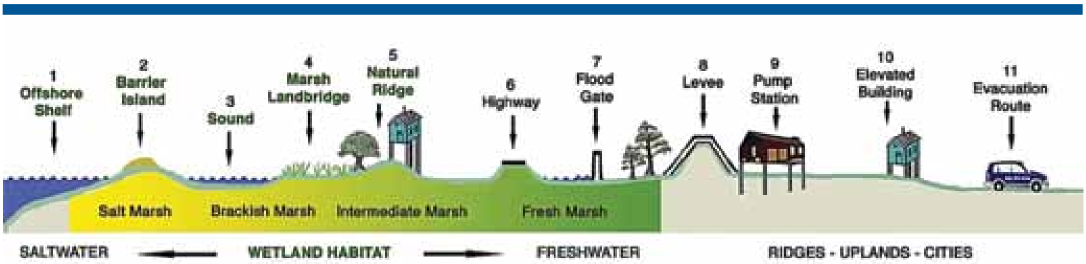
2. Transportation, including all roads, bridges, public transit, pedestrian amenities, bicycle, port, and airport infrastructure and systems

3. Broad aspects of sustainability, environmental quality, and resilience as they relate, in particular, to green design, energy efficiency, flood protection, stormwater management, hazard mitigation and emergency preparedness, and coastal restoration.

The January 2010 draft of the master plan includes a general recommendation that the City of New Orleans create a climate plan that addresses how the city should respond to global warming (Goody Clancy 2010: 4). Adaptation and mitigation measures recommended to respond to changing global weather patterns in the near term include reducing neighborhood flooding by preserving wetlands within and outside of the city's levee system and, following the anticipated completion of current levee reconstruction efforts, elevating houses above projected 500-year flood levels (generally three to six feet). This master plan recognizes that the future safety and resilience of New Orleans depends on multiple lines of defense from storm surge and relative sea level rise (figure 3.6), and that natural and built systems can provide such defenses (Lopez 2006). This strategy entails coastal wetlands and barriers, levees and pumps, internal drainage improvements, and land use planning and regulation. The plan also stresses that placemaking in New Orleans must be sustainable by interrelated strategies, including responding to natural systems; conserving energy; enhancing public and personal health; enhancing food production and distribution; protecting water resources; and addressing climate change.

In the winter of 2009 to 2010, the New Orleans City Planning Commission approved the new master plan's recommendations for future land use, which will serve as the foundation upon which the city will implement the "force of law" provisions of the 2008 amendment to the city charter. While the Master Plan and Comprehensive Zoning Ordinance (CZO) project offers an opportu-

Figure 3.6 Concept of Multiple Lines of Defense for Restoration of Coastal Louisiana
Source: Lopez (2006).



nity to include resilience strategies, the city's structural and nonstructural land use needs depend on the contextual large-scale coastal restoration that is outside the jurisdictional boundaries of Orleans Parish.

The land uses recommended by the planning commission have not deviated from land uses related to zoning that were in place prior to the master planning development. However, suggestions have been offered for exploring numerous land uses in residentially zoned areas to which residents have not returned. For example, from the public comments received during the master plan development, a high priority was placed on using the Dutch system of water management exemplified by the Room for the River program, adopted by the government of the Netherlands in 2006, to hold more water within the city by constructing more canals and retention ponds and repairing and improving pumps and levees. Paradoxically, due to concerns about flooding, mosquito-borne disease (one of the main public health concerns that resulted in wetland dewatering in the first place), and a prevailing notion that the best way to manage water is to keep it outside of the city's boundaries, little public support exists for instituting a comprehensive water management system or using parks or vacant land for water storage. These seemingly contradictory impulses still remained to be resolved and included in a recommended citywide master plan or strategy.

State Buyouts of Residential Properties

Further complicating the transition from residential to other land uses—including introduction of more natural habitats such as water, greenspace, and urban forest into areas of the city where a low percentage of residents are returning—is a lack of public trust in both government and developers. Maps produced during the immediate aftermath of Hurricane Katrina by the Urban Land Institute (ULI) and the BNOBC's Urban Planning Committee depicted portions of low-lying residential areas as converted into wetlands or greenspace (figure 3.7). These images were introduced to homeowners prior to development of the Road Home program, which provided voluntary buyouts and restoration grants. Thus, these proposed conversions to nonresidential uses were generally perceived not only to decrease the market value of surrounding residential property, but also as a potential plot aimed at denying residents the right to return to their former homes. The maps and proposed land uses were met with public hostility and in 2006 became important artifacts in a contentious and racially charged mayoral election.

In particular, the public discourse regarding the fate of the Lower Ninth Ward neighborhood spawned accusations that an effort was being made to dispossess landowners in favor of industrial development or greenspace. Mayor Nagin publicly responded to criticism leveled at the ULI and BNOBC maps by stating emphatically that the return of African-American residents was his priority, and that no neighborhood would be targeted for abandonment or conversion to greenspace (Baum 2006). Even though Nagin categorically ruled out the use of eminent domain, many areas of the city have been slow to repopulate.

As of February 2010, more than four years after Hurricane Katrina, in numerous areas of New Orleans fewer than 50 percent of the former residents have returned. Green and Olshansky (2009) evaluated the extent to which New Orleans homeowners exercised buyout options offered in the Road Home program (i.e., selling their property to the Louisiana Land Trust rather than returning to their pre-Katrina property). Figure 3.8 shows that numerous significant clusters of sellers participated in this voluntary program. Not surprisingly, all of these clusters are in lower-lying areas that suffered the greatest impact from the post-Katrina flooding. In several cases, they are also in regions of the city that the BNOBC Urban Planning Committee recommended for potential land use changes to encourage open parkland.

Figure 3.7 Prospective Renderings of the Hoffman Triangle Neighborhood in Mid-city New Orleans

Source: http://dutchdialogues.com/2010/05/03/dutch-dialogue-2/

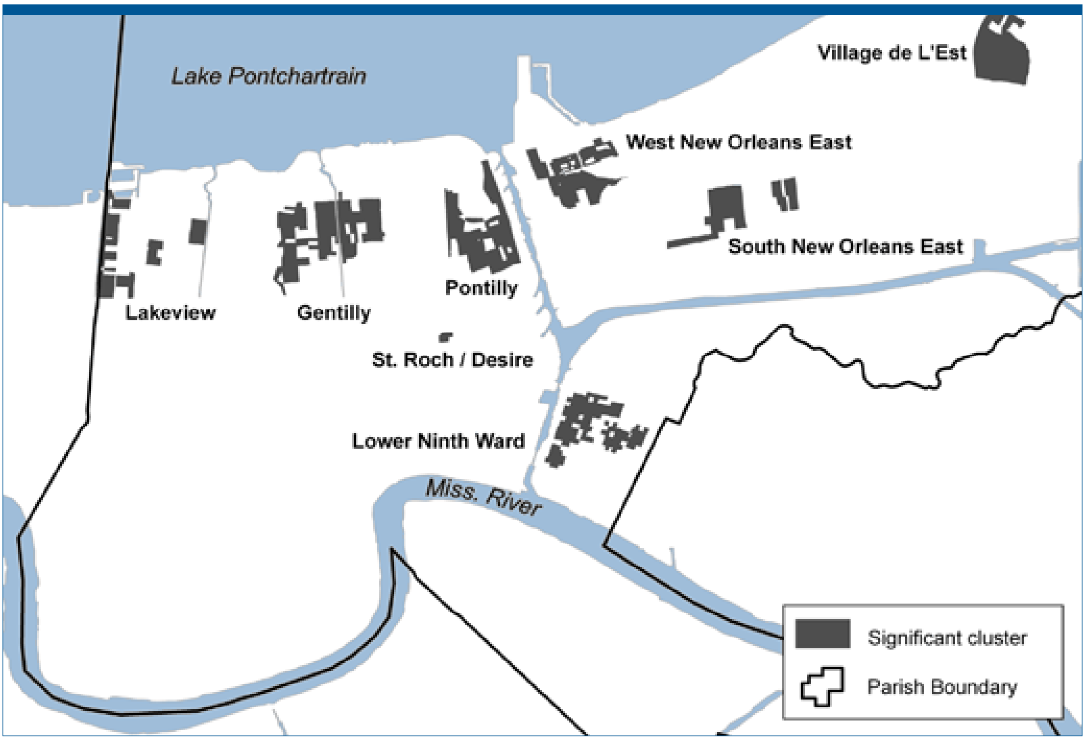
These renderings contrast current residential development trends (top) with proposed water-management interventions similar to those used in flood-prone areas in the Netherlands.

Coastal and Neighborhood Planning for Recovery and Restoration

The Mississippi River Gulf Outlet

Navigation canals have altered the hydrology of coastal Louisiana fundamentally. Before the National Environmental Policy Act of 1970, dredging a canal in the coastal swamps and marshes required little more than the economic impetus and land rights to move forward. One of the more significant sources of wetland loss on the eastern flank of New Orleans is the controversial Mississippi River Gulf Outlet (MR-GO) channel, known locally as "the Mr. Go." The controversy about the channel illustrates both the failures of ecosystem

Figure 3.8 Significant Census Block Clusters in Which Many Homeowners Sold Their Property
Source: Green and Olshansky (2009).



management in the region and how the trauma of Hurricane Katrina catalyzed citizens, politicians, and government agencies to take measures to address the degradation of the city's eastern marshlands and the associated flood risks to the metropolitan area.

Authorized by Congress in 1956, completed in 1968, and closed in 2008, the MR-GO was a major navigation canal dredged by the U.S. Army Corps of Engineers for the Port of New Orleans as a shortcut for deep-draft ships to enter the port's Inner Harbor Navigation Canal (figure 3.9). Historically, larger ships were required to access Port of New Orleans facilities via the lower passes of the Mississippi River. In contrast to the river's circuitous route and shifting sand bars, the MR-GO was a 75-mile straight shot, designed to a depth of 36 feet, and a width of 500 feet. The channel's banks were largely unprotected from wave action, and in some areas it widened to more than twice its design width (USACE 2007). Saltwater from the Gulf of Mexico crept inland through the channel, penetrating the swamp forests dominated by cypress and tupelo trees. In just 15 years, the cypress and tupelo forests along Bayou Bienvenue, some within the city's political boundaries, exceeded their salinity thresholds and transformed into open water and patches of marsh grass. The resultant loss of storm surge buffering services, biodiversity, and the devastation of the local fishing and trapping industries were immense.

By 1990 nearly 70,000 acres of wetlands had been destroyed or transformed (USACE 2007).

Although the potential impacts of the project were apparent to some observers from its inception, prior to Hurricane Katrina social movements advocating for the channel's closure were largely fruitless. In the wake of the 2005 hurricanes, however, MR-GO became synonymous with the Corps of Engineers' failures during the twentieth century, and debates raged regarding whether Katrina's storm surge was in fact ushered into the city via the channel. Articles from the *Times-Picayune* and other media outlets frequently referred to MR-GO as a "hurricane highway." Intense criticism from environmentalists and local politicians, who lobbed charges of poor management of the project at the Corps of Engineers, brought Congress to enact the Water Resources Development Act of 2007, which mandated closing the channel. Two years later, a landmark federal court decision found the Corps liable for certain flood damages in Orleans and St. Bernard Parishes due to its negligent management of the MR-GO (*Robinson v. United States*, Civ. A. No. 06-2268 [2009]).

The closure and restoration plan for the MR-GO is extensive and incorporates much of the Pontchartrain Basin, Lake Borgne, and the Mississippi Sound (USACE 2009). The closure plan includes three chief components, the first of which is a rock salinity dam installed between New Orleans and the Gulf of Mexico in hopes of restoring historical salinity regimes. The second component is a comprehensive ecosystem restoration plan being developed by the Corps of Engineers to restore swamp and marsh ecosystems over a vast territory. More than $100 million was authorized for this project, but the funding apparatus that will underpin this extensive restoration is still uncertain. For example, as of July 2010, surface oil from the BP oil spill had been observed throughout the restoration area, so perhaps the Obama administration will allocate oil spill funds for this ecological restoration.

A formally separate but related storm surge barrier built across the marshes where the MR-GO and the Gulf Intracoastal Waterway intersect—an area sometimes referred to as "the funnel"—is the final major

Figure 3.9 MR-GO Navigation Canal and Other Waterways East of New Orleans

Source: NASA Landsat imagery processed by Joshua Lewis.

component of the plan. This surge barrier is the largest domestic design-build civil works project ever undertaken by the Corps of Engineers (USACE 2010a). It is designed to prevent hurricane storm surges from entering the Inner Harbor Navigation Canal, which flooded much of eastern New Orleans following Hurricane Katrina.

The MR-GO case demonstrates that, while agencies like the Corps of Engineers are often insufficiently responsive to degrading ecological conditions and other slowly changing variables, such as climate change–induced sea-level rise, large, politicized disasters like Hurricane Katrina and the BP Deepwater Horizon oil spill can initiate sweeping reforms if the actors and events cooperate.

The Lower Ninth Ward

Community-based planning efforts in New Orleans have explored several strategies that embrace sustainability concepts for rebuilding and land use, and the Lower Ninth Ward offers a promising case study. As early as June 2006, the Lower Ninth Ward and its Holy Cross Neighborhood produced a sustainable restoration plan that contributed to the NONRP and UNOP processes. Key concepts examined in the plan include structural improvements, such as energy efficiency and renewable energy, and naturalistic interventions for open or degraded spaces that promote safety, survivability and, ultimately, carbon neutrality (e.g., cypress swamp restoration and urban forestry).

For example, in the areas at lower elevations in the Lower Ninth Ward, the community is supporting restoration of the adjacent Bayou Bienvenue in order to provide storm surge protection, wastewater assimilation from the neighborhood's water treatment plant, carbon sequestration, and recreation services. For residential areas that experienced little home reoccupation and a high percentage of participation in the state's buyout option, ideas have been proposed that range from urban farming and forestry to community gardens and parks. In January 2010, the Lower Ninth Ward's Center for Sustainable Engagement and Development (CSED) initiated a re-examination of the Holy Cross Neighborhood's 2006 goals in the context of repopulation realities to assess community support for investments in land use, transportation and infrastructure, and building and energy efficiency goals that support climate change mitigation and adaptation.

If a new residential use does not materialize for the properties throughout the city that were bought out through the state program, a land use change and new "active" use would likely increase the market value for surrounding repopulated parcels in those neighborhoods, making the result very fortuitous. But whether these clusters will see significant permanent land use changes that incorporate water and/or park systems remains to be seen. However, with maintenance of community engagement—continued CSED engagement in the Lower Ninth Ward, for example—the passive stormwater runoff and retention as well as the aesthetic and recreational ecosystem services of these adaptation measures can lead to greater community support for investments in such interventions. To that end, the city and its residents' ability to see water not only as a threat, but also an asset—to live *with* water rather than *against* it—will be a critical evolution from norms that currently prevail.

Nonprofit and industry investments in demonstration projects for sustainable architecture throughout New Orleans have also provided a variety of climate mitigation examples. In the Lower Ninth Ward, investments in sustainable rebuilding by the Make It Right Foundation and Global Green have either completed or at least started building 80 homes (75 for Make It Right). All received the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) certification, and Make It Right anticipates building more than 70 additional LEED-certified homes. If successful, in relative terms these efforts would comprise the highest concentration of LEED-certified residential units in the United States.

In addition, in 2006 Sharp Solar collaborated with the Holy Cross Neighborhood Association, Lower Ninth Ward Neighborhood Empowerment Network Association, CSED, Preservation Resource Center, and the Alliance for Affordable Energy to donate ten solar panels for community centers and neighborhood residents. While these panels obviously will not be responsible for a significant reduction in the city's overall carbon footprint, their installation catalyzed the city's first solar power retrofit of a historic home and its inaugural demonstration of net metering, setting the stage for systemic citywide reductions in GHG emissions through renewable energy, advancement of city and state incentives for installation of renewable energy technologies, and development of policies for a renewable energy portfolio standard for the city's single electric provider, Entergy New Orleans.

Though the relationship between the Army Corps of Engineers and the Lower Ninth Ward's civic groups has always been contentious, the closure of the MR-GO has created new opportunities for building trust and collaboration. For example, the MR-GO restoration plan will include recreational features intended to build upon an existing neighborhood initiative to reconnect residents to the wetland area that lies just to the north of their community (USACE 2010b).

Scale Mismatches in Regional Planning and Land Use Governance

As described previously, part of the challenge facing New Orleans' master planning and zoning ordinance process is that it depends on complementary regional plans implemented on the parish and state levels. On this scale, regional planning is subject to a fragmented, uncoordinated land use planning and governing structure. The recent escalation in the costs of restoration and levee protection along with the decline in the price of domestic oil and gas revenue from Louisiana, which reduces the state's ability to generate matching revenue for coastal restoration and protection projects, adds further obstacles to implementing the coastal plan. Even with adequate funding and access to land, the construction of more robust levees and restoration of wetlands will likely take at least a generation to implement. By the end of this century, the dramatic wetland loss coupled with the relative sea level rise that is occurring in many parts of deltaic Louisiana may leave salvageable for human habitation only the thin ridges that flank the Mississippi River, various bayous in rural coastal Louisiana, and the dense, impounded urban areas near and below sea level.

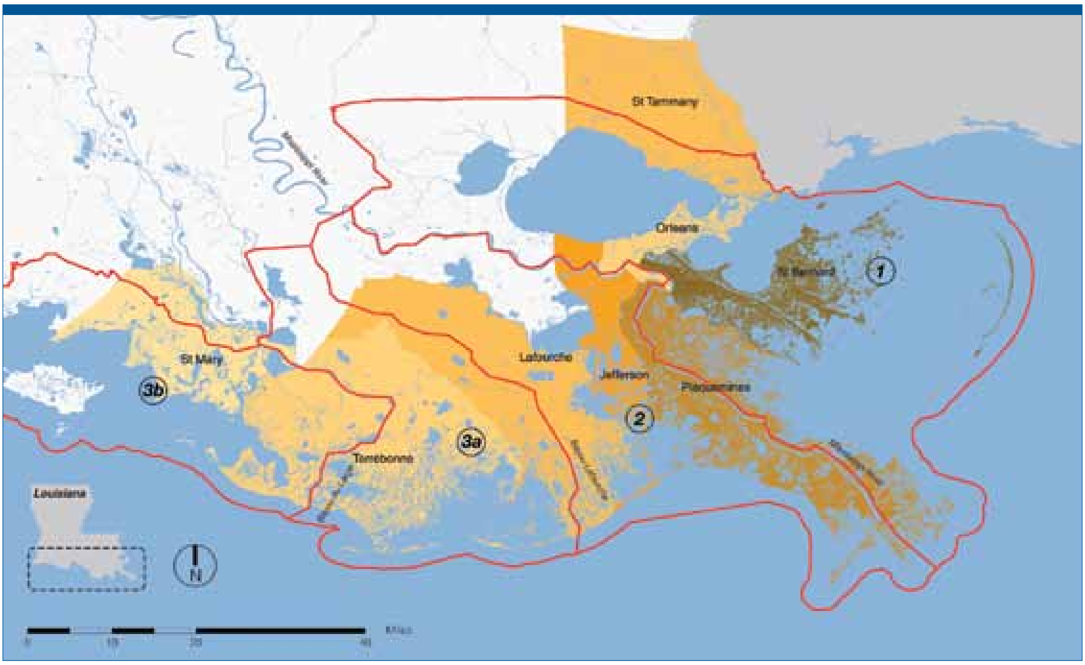
Systematic planning interventions in coastal Louisiana are further complicated by mismatches between the natural boundaries and those of the jurisdictions that hold the requisite regulatory authority or planning capacity. Figure 3.10 shows four of the five coastal ecosystem–based planning units (based on combinations of major watersheds and basins) overlaid on jurisdictional boundaries governed by parishes. Jurisdictional mismatches exist because settlement and subsequent local governance in coastal Louisiana tend to straddle the high ground on coastal bayou and river levees, while the hydrologic-based planning units of the Coastal Protection and Restoration Authority (CPRA) are often demarcated by these same waterways, which is counterintuitive to most watershed-based planning in areas with greater vertical topography.

On this spatial scale, New Orleans is exemplary of a municipal land use authority that has planning and regulatory jurisdiction over just a fraction of the pertinent area. The official regional planning commission for the five parishes around New Orleans is a policy body that has no regulatory authority and falls short in terms of geographic coverage relative to the larger coastal system and the ecosystem planning units labeled 1 and 2 in figure 3.10.

Agencies of the state and federal governments are positioned to maintain and protect the larger system and to regulate uses that impact coastal waters and wetlands, but they may have neither the mandate nor political will to intervene in land use matters that involve private property. These agencies include Louisiana's Office of Coastal Protection and Restoration (OCPR) and the Louisiana Recovery Authority (LRA), and at the federal level FEMA, the Environmental Protection Agency, and the Army Corps of Engineers. Since Hurricane Katrina, however, the state has integrated its levee protection and coastal restoration programs (formerly under the state's Departments of Transportation and Natural Resources, respectively) in the new OCPR (CPRA 2007). Through this office, the state produced the first coastal master plan for large-scale restoration in 2007 and provided annual updates in subsequent fiscal year plans (CPRA 2009; 2010; and 2011). A second master plan is due in 2012.

Linking coastal restoration to its economic value supporting climate change mitigation, Louisiana currently is promoting itself as a leader in GHG sequestration by establishing standards for and quantifying the volume of

Figure 3.10 Planning Units of Louisiana's Coastal Protection and Restoration Authority Master Plan
Source: Jonathan Tate.



Note: Numbers reference hydrologic planning units. Shaded areas indicate parish (county) boundaries.

GHGs captured as a result of coastal restoration and other vegetative plantings. The carbon-sequestration benefits of Louisiana's coastal wetland and forested habitats are emerging as increasingly significant drivers in the exploration of various land use policies that promote restoration and conservation of these private and public lands. For example, an acre of restored bottomland hardwood in the lower Mississippi floodplain could sequester up to 300 tons (average of 100 tons per acre) of carbon dioxide over the next 100 years (Wayburn 2009). In addition, the highly productive, brackish marshes of Louisiana's coastal zone contain among the highest amounts of organic soil carbon in the United States, thus representing even greater opportunities for carbon sequestration (Markewich and Russell 2001).

Disaster Plans

New Orleans Disaster Preparedness

Hurricane Katrina catalyzed a series of plans for both disaster recovery and planning for future disasters. Orleans Parish adopted an official hazard mitigation plan in December 2005 with a 2010 update completed in March 2011. The city's Office of Homeland Security and Emergency Preparedness Hazard Mitigation Unit has the following objectives.

- Communicate hazards and risks to New Orleans residents in coordination with the Offices of Emergency Preparedness, Communications, and Recovery; the LRA; Governor's Office of Homeland Security and Emergency Preparedness; FEMA; and Army Corps of Engineers;
- Develop comprehensive solutions, policies, and programs to manage hazards and risks in coordination with the Department of Safety and Permits, Office of Emergency Preparedness, and City Planning Commission;
- Build long-term capacity in hazard mitigation and risk reduction, including acquiring funds for hazard mitigation projects;
- Include knowledge about hazards and risks in city planning and project development processes; and
- Incorporate hazard mitigation and risk reduction principles and requirements into the city's master plan and municipal code.

Related action items in the city's hazard mitigation plan include:

- Enhancement of the metropolitan area's levee system to withstand a Category 5 hurricane;
- Providing Orleans Parish with a review of the maintenance and strength of the levee system in coordination with the relevant levee district;
- Ensuring that the city's codes are consistent with FEMA regulations;
- Development and maintenance of a comprehensive geographic information system that includes disaster planning, preparation, and recovery data;
- Enhancing public awareness of vulnerability and promote the purchase of flood insurance;
- Developing a comprehensive program to protect vital records; and
- Participation in and support of regional and state efforts for coastal restoration.

By addressing areas with high-frequency flood risk as well as those with low-frequency but high-consequence flood risk, the city's current proposed final master plan supports demonstration projects consistent with Louisiana's coastal master plan. It includes:

- Property buyouts in low-lying, high risk areas allowing for relocation elsewhere in the city, state, or United States;
- Relocation to new elevated structures in the same or adjacent neighborhoods;

- In-place elevation of damaged structures (minimum of 3 and maximum of 15 feet);
- Secondary levees and floodwalls (with height up to 6 feet) around critical public facilities or commercial buildings;
- Dry flood proofing of commercial buildings (installation of external waterproof walls up to 4 feet in areas with a history of flooding up to 3 feet at most); and
- Hardening of critical facilities through elevating pumps, generators, electrical wiring, etc., and moving operations above the first floor.

In terms of evacuation, the city's master plan suggests that New Orleans' long-term economic viability will be threatened if mandatory evacuations of a week or more occur in any given year. To date, the Corps of Engineers has been authorized and mandated by Congress to establish only a 1-in-100-year level of flood protection by 2011, mandated by Congress to establish only a 1-in-100 year level of flood protection by 2011—a standard deemed insufficient by the National Academy of Sciences and the City Planning Commission. The city has endorsed a minimum level of protection for a 1-in-500-year flooding event (Goody Clancy 2010:9). While long-term strategies eventually may eliminate the need for large-scale evacuation, potential annual evacuation plans will remain critical in New Orleans for years to come.

Given the gross inadequacy of the city's evacuation plans before Hurricane Katrina, its government and the U.S. Department of Homeland Security developed a new city-assisted evacuation plan (CAEP) to aid any residents who lack means to leave the city during a mandatory evacuation. This plan was still in its infancy in 2008, when Hurricane Gustav triggered the first post-Katrina mandatory evacuation. City, state, and federal agencies were involved at various stages in the operation. No "shelters of last resort," such as the Louisiana Superdome during Hurricane Katrina, would be open for residents who stayed behind.

At the municipal level, hundreds of citizen volunteers were mobilized to help staff evacuation points and ensure that the cumbersome process went relatively smoothly. More than 20,000 residents were safely ushered to hurricane shelters throughout the southeast. The evacuation before Hurricane Gustav also led a group of volunteer coordinators to found Evacuteer.org, a nonprofit charged with recruiting and mobilizing volunteer assistance for the CAEP. Evacuations are always economically and socially disruptive, but New Orleans' experience with Hurricane Gustav demonstrated that if a major storm again threatened, the city's infrastructure and the various institutions and agencies could successfully evacuate the population to safety and direct them back to their homes once danger abated.

The Inner Harbor Navigation Canal surge barrier is the largest design-build civil works project ever awarded by the U.S. Army Corps of Engineers.
Photograph © Joshua Lewis.

Regional Disaster Preparedness

Human populations worldwide will continue to occupy urban areas that are vulnerable to the impacts of both slow variables (e.g., sea level rise, periodic flooding) and threshold events, such as natural disasters. The Gulf Coast of the United States has an ongoing history of severe storms. A major hurricane has hit somewhere along the coast every year since 1994, with 26 named storms and 14 hurricanes making landfall during 2005 alone. One of the reasons that Hurricane Katrina caused so much damage is that currently more than 10 million people—3.5 times the population that lived there in the 1950s—live in U.S. coastal counties and parishes along the Gulf of Mexico (NCMGCEC 2006). The integration of coastal restoration and levee protection during the aftermath of Hurricanes Katrina and Rita has resulted in more investments in hurricane protection projects that are governed through the CPRA.

Since Hurricane Katrina, numerous articles and reports have linked the theoretical underpinnings of coastal science, engineering, architecture, landscape architecture, and urban planning and design with basic land use and other germane coastal policies to provide recommendations for future planning of the urban/rural form of New Orleans and its surrounding deltaic landscape (Blakely 2007; Costanza, Mitsch, and Day 2006; CPRA 2007; Laska and Morrow 2006; Tornqvist and Meffert 2008). Most documents emphasize adaptation as well as mitigation and recognize that adaptive measures are necessary, given the rapid rate of relative sea level rise and increased salinization of freshwater and brackish coastal marsh habitats in the region. In general, recommendations include maximizing incorporation of natural ecological processes in community-based planning and design and minimizing deleterious environmental impacts of built infrastructure elements. Specific recommendations vary among publications, but most include one or more of these general concepts.

1. Work with natural hydrology and propensity for flooding, and encourage (a) building on higher ground and increasing residential density in such areas; and (b) promoting decreased residential density in lower-ground and floodable structures.

2. Restore natural landscapes, such as graduated boundaries and topography between deepwater systems and uplands, using natural processes (e.g., diversions of the Mississippi River) to attain maximum provision of ecosystem services, including storm surge and infrastructure protection.

3. Implement flood control, disaster preparedness, and landscape interventions on a neighborhood scale, and institute primary transportation corridors (e.g., terraces; polders; and drainage enhancements, including bayous, canals, and permeable surfaces).

4. Use sustainable architectural practices that bring into the equation renewable and efficient energy, decreased flooding propensity, and materials reuse, both for renovating existing structures and constructing new structures.

5. Maximize community participation and restore social capital—diversity, environmental justice, and social networks—at every phase of planning, design, and implementation.

The Influence of the Netherlands on Climate Adaptation in New Orleans

The Netherlands' policies and practices regarding storm protection and water management provide useful tools that are influencing Louisiana's current climate change adaptation as well as the state's retrospective examination of its historic coastal landscape manipulations and periodic flooding. In terms of historic drainage of coastal ecosystems in order to promote urbanization and other land uses, it was Albert Baldwin Wood's patented hydraulic pumps, invented in New Orleans and presented in 1913, that the Netherlands, China, Egypt, and India ultimately adopted (Campanella 2008).

Since Hurricane Katrina, a number of intellectual exchanges have occurred between Dutch and Louisianan stakeholders on "living with water," both on an urban scale as well as in a larger, coastal context. These dialogues have culminated in master planning aids including the *Dutch Dialogues* (Meyer et al. (2009), with support from Waggonner & Ball Architects, the American Plan-

Table 3.2 Mississippi and Rhine Rivers Compared
Source: Meyer et al. (2009).

	Mississippi River	Rhine River
Length	6,275 km	1,320 km
Average depth	at New Orleans: 60 m	at Arnhem: 8 m
Average discharge	16,000 m^3/sec	2,000 m^3/sec
Extreme discharge	48,000 m^3/sec	12,000 m^3/sec
Sediment transport	170 million tons/year	0.4 million tons/year

ning Association, Delft University of Technology, and the Netherlands Water Partnership, as well as New Orleans' master planning process executed through Goody Clancy.

Louisiana and the Netherlands face similar challenges in terms of living with an abundance of water as well as the similar sizes of their respective deltas, although significant contrasts in scale and size of their respective rivers are also recognizable (table 3.2). The Mississippi River is 10 orders of magnitude greater than the Rhine in terms of average discharge and 425 orders of magnitude greater in terms of sediment transport, thus offering more potential for rebuilding deltaic habitats to offer natural storm surge protection and other ecosystem services; but there is much more demand for maintaining the large deltaic system of coastal Louisiana.

Nearly 27 percent of the Netherlands' land is below sea level, and that area is home to 60 percent of the country's population (9.48 million people). In terms of planning and governance, the Dutch have developed water boards that historically have governed the planning and construction of flood control structures to protect people, farmland, and cities. In the twentieth century, the construction of major flood control structures deemed necessary to protect large regions of the country from increased storm and flooding threats from the North Sea enhanced the applied scientific and engineering advisory capacities of these boards. Delft Hydraulics, created in 1927, was the first of these organizations, and it was followed by the Netherlands Organization for Applied Scientific Research (TNO) in 1932, GeoDelft, and sections of the Rijkswaterstaat later in the century.

In 1953, the North Sea flood inundated the coastlines of the Netherlands and England, killing nearly 2,000 people and inundating 850 square miles of land. The total damage at the time was 895 million Dutch guilders (€5 billion, or approximately US$7 billion in 2011 currency). In response to this disaster, the country instituted its first Delta Commission to develop plans that would prevent future flood disasters and constructed Delta Works, one of the most ambitious public works projects in modern history. The current system has more than 1,800 miles of sea dikes and 6,200 miles of inner canal and river dikes. In addition, the system includes approximately 300 structures that support navigation and flood control between the diked systems. While these engineering solutions have protected the Dutch from severe flooding since 1953, they also exacerbated the erosion of approximately 1,000 square miles of coastal wetland into open sea, which is roughly comparable to the 2,300 square miles of coastal wetland lost in Louisiana during this same time period.

In terms of climate change impacts, not only will the Netherlands suffer from the effects of sea level rise, but more severe summer droughts and periods of more intensive rainfall in the winter are likely to become commonplace (De Wit 2009). Most of the climate change adaptation efforts in the Netherlands have centered on spatial planning efforts to give water more space. This policy, known as the Netherlands' Room for the River approach involves lowering dikes in targeted areas to improve flood protection in other areas that are home to large populations or valuable infrastructure. While it may seem counterintuitive, the practice of allowing certain natural habitats or farmlands to flood during high river stages can reduce the vulnerability of nearby urban centers.

A New Orleans analog was constructed in response to the 1927 Mississippi River Flood and first opened in 1937. The Bonnet Carré Spillway located 12 miles west (upstream) of New Orleans was built as a flood control measure. This 1.5-mile-wide, mechanically controlled concrete weir constructed parallel to the Mississippi River generally has been opened only when the river approaches its flood stage of 17 feet. With 250,000 cubic feet per second capacity, the spillway has been opened nine times during its 80-year history (Scallan 2008). Floodwaters are released into Lake Pontchartrain north of New Orleans and ultimately flow out into the Gulf of Mexico. Sediments deposited in the spillway and the lake have been used for multiple urban environmental projects ranging from coastal restoration (e.g., the LaBranche Wetlands) and as clean top soil to remediate lead-contaminated residential land and schoolyards in New Orleans. Not only could future projects use natural systems as flood control solutions, they could utilize these diversions to restore and create new wetlands as well. For population centers in both the Netherlands and New Orleans, increased water storage practices, such as catch basins, green roofs, gardens, recreation parks, waters squares, and pervious surfaces, are encouraged in existing and future urban development strategies.

In terms of governance and process, Louisiana's coastal policy stakeholders are looking at the Dutch model for large-scale watershed planning and policy that could support the proposed authority to oversee coastal restoration. Under the leadership of Senator Landrieu, a coalition comprised of local, state, and federal agencies; academic and nongovernmental organizations; industry; and community stakeholders convened in the fall of 2009 and throughout 2010 to formulate ways to apply the collective partnerships forged in the Netherlands to multiscale water and coastal restoration and climate change adaptation for natural habitats, rural communities, urban centers, and associated economies and cultures.

Conclusions

As a deltaic city, New Orleans has always been situated in a dynamic landscape. The rates of relative sea rise and coastal erosion for the New Orleans region are among the highest in the world. That factor combined with the region's relationship to the predicted increased intensity and, possibly, frequency of hurricanes, makes New Orleans particularly vulnerable to climate change. Thus, it provides valuable clues for adaptation of vulnerable deltaic cities worldwide in terms of sea level rise, flooding, and hurricane impacts associated with climate change.

The increased susceptibility of New Orleans and coastal Louisiana does not argue for abandonment of the region. In addition to its rich cultural heritage, New Orleans and its surrounding coast provide vast tangible economic value to the world in terms of fisheries, oil and gas production, and waterborne commerce. Based on increased understanding of the limited ability of Louisiana's coastal wetlands to maintain sufficient elevation relative to the rising sea level, the future design of the natural and built environment must also accommodate periodic flooding and increased vulnerability to storm surge.

In New Orleans and along the Gulf Coast, the prevailing urban and regional planning responses to climate change have emphasized adaptive measures rather than those accommodating mitigation. In terms of climate change adaptation in city planning, for example, New Orleans has enforced raising homes to new base flood elevations established after Hurricane Katrina. Its master plan's land use recommendations do not promote new developments in remaining wetland areas within the city's boundaries. These measures are dependent on enhanced levee and floodwall protection around the metropolitan area and regional coastal restoration efforts that are largely governed by the State of Louisiana and the Army Corps of Engineers.

Many opportunities for mitigation remain, such as increased GHG sequestration through restoration of natural delta processes and wetland creation; GHG regulation of oil and gas industries in the state; GHG reductions effected through increased use of renewable energy sources; and energy efficient construction methods as an integral part of disaster recovery. These measures are still in early stages of development, however, and are largely voluntary and market-driven on local, state, and federal levels. GHG regulation of oil and gas industries, in particular, is not supported at the local, state, or federal congressional-delegate levels because revenue streams arising from these industries are a major component of Louisiana's economy and, paradoxically, remain the most reliable near- and long-term source of funds to support Louisiana's coastal restoration. In addition, coastal restoration projects implemented to date have generally been smaller in scale and more limited in terms of restoring large-scale natural processes. Much remains to achieve in terms of realizing Louisiana's wetland potential for carbon sequestration.

Examples of mitigation in municipal planning and disaster recovery in New Orleans remain merely anecdotal demonstrations, rather than systemwide policies. For example, while the New Orleans City Council has considered a renewable energy portfolio standard, this policy is still in the development stages and does not have full support of the city council. As a positive, albeit ironic advance in local mitigation, the devastation to New Orleans and surrounding coastal areas has catalyzed unique demonstrations in GHG mitigation exemplified through low-carbon construction, energy efficient architecture, and installation of solar and other renewable energy approaches throughout the city, none of which existed there before Hurricane Katrina, and are unlikely to have been implemented on the current scale without that impetus.

The challenge ahead rests primarily on two issues: limited funding and land use policy implementation at the city scale as well as that of the coastal region. The BP Deepwater Horizon oil spill represents the second recent major disaster to hit the Louisiana coastal region and, as with Hurricane Katrina, it provides a window for dramatic policy innovation as well as new funding streams to support large-scale restoration. Since the 1930s, the Louisiana coast has advanced 20 miles toward New Orleans due to coastal erosion. The added impacts of relative sea level rise will convert New Orleans into a coastal city by 2100. By then, 50 percent of it may be below sea level, unless coastal restoration efforts, including re-establishment of large-scale delta building over millions of acres, are successful.

Accomplishing this goal will require enormous monetary investment and the relocation of tens of thousands of residents into areas that will be less prone to flooding, such as locations at higher elevations and those with greater levee protection in the more densely populated areas. While Louisiana has a long record of rapid implementation of land takings in order to accommodate adaptive measures, such as levees and pumps, its record on takings or other creative land use options that would maintain private landownership for large-scale coastal restoration adaptive measures is limited. From this perspective, the science and engineering behind citywide and coastwide adaptation is well studied, whereas the legal and financial hurdles require much greater investment in decision making and new directions for policy.

Due to the contentious nature of each coastal restoration project and the need for federal monies, collective action among state and local political actors is imperative for securing funding. Future state-originated coastal master plans will acknowledge that not all parts of Louisiana's coast can be sustained, and a spending-averse Congress is unlikely to fund a program that it considers unrealistic. Congress is also unlikely to fund projects that are in the midst of litigation, or those for which local opposition is sufficiently vocal to attract third-party players, such as news media and other actors in civil society.

Although future coastal master plans will acknowledge that community relocations are necessary, reaching consensus on projects that will likely disrupt and transform ecosystems and force communities to relocate is daunting to say the least. After Hurricane Katrina, the suggestion of mandatory moving of residences within the parish boundaries was met with such opposition that these proposed relocations quickly became untenable for local politicians. How this same phenomena plays out for rural coastal parishes in the decades to come remains to be seen, but targeted relocations clearly will be necessary.

Local and state leaders must address this inevitability head on and support concomitant, fair monetary compensation. More specifically, the state will need to identify coastal parish properties where residential relocations or other land access will be necessary for implementation of large-scale restoration and flood control, consistent with its coastwide master plan. For these properties, where voluntary land use transitions cannot be achieved, takings or other land access mechanisms will be necessary and property owners should be compensated with the fair market value of their properties or their use. Without this proactive approach to relocations, it is unlikely that Louisiana will get the national political and financial support it needs for large-scale coastal restoration.

The visibility of Hurricane Katrina and the Deepwater Horizon oil spill demonstrated to Louisiana's urban residents as well as Americans across the country the critical condition of the state's coastal wetlands. This added a new cadre of engaged citizens and national environmental organizations working to fund of restoration projects. This new paradigm introduces ample enthusiasm, but also another layer of political complexity. Parish-level restoration advocates are perhaps most likely to support projects that generate ecosystem services within their parish's boundaries. For example, the perception that coastal restoration projects are designed to protect and generate services only for New Orleans is widespread in nearby St. Bernard Parish. Growing resentment by rural-parish governments can be seen in public hearings concerning the MR-GO ecosystem restoration plan. In one such meeting, St. Bernard Parish President Craig Taffaro emphasized his view that "St. Bernard Parish is more than a barrier for the rest of metropolitan New Orleans." (Taffaro 2011) To an extent these tensions are unavoidable, but historical animosity between communities must not be inflamed by an approach to restoration that rewards competition between parishes to secure projects they perceive as being most favorable to their residents.

Regarding urban planning in Orleans Parish, local planners, managers, and leaders remain challenged in terms of implementing projects prioritized as a result of the UNOP process and the 2010 comprehensive zoning ordinance. The official 2010 census population of Orleans Parish is 343,829 residents, which is approximately 120,000 fewer residents than the pre-Katrina population and roughly 50 percent of the city's population in the early 1960s, when the city's footprint was half its current size. Between March 2007 and August 2010, the number of unoccupied addresses declined by 30,000, but nearly 64,000 residential and commercial properties in the city remained unoccupied (GNOCDC

2010). This population decline is expected to cause Orleans Parish to lose at least three districts in the state's House of Representatives and one state senate seat. In addition, the current expectation of a 1-in-100-year level of flood protection is one that the city deems insufficient to attract new residents and industries into the area and, yet, no funding stream has been identified to increase the protection level. Local leaders must support and implement creative uses (e.g., parks and urban gardens) for vacant lots in which residential use will not recur. These investments will improve the adjacent property values and serve the residents who have come back to these respective neighborhoods.

Looking toward the end of the twenty-first century, reasons for both optimism and pessimism exist. On one hand, although the City of New Orleans has no jurisdiction over the state's other coastal parishes, the environmental crisis combined with current governmental leadership is fostering new municipal partnerships with the state. From these partnerships, creative models are emerging for large-scale watershed management, and funding is being used to address the challenges of climate change while preserving the economic, ecological, and cultural services that the region provides to the United States and the world. Numerous challenges remain for metropolitan planning in New Orleans. The city's viability and survival into the next century is not guaranteed and greatly depends on the achievement of massive coastal protection and restoration goals on a scale never before attempted in the world.

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Figure 4.1 **Los Angeles–San Diego**

Source: Weiss and Overpeck, University of Arizona.

dark blue overlay areas = low-lying coastal areas of ≤ one meter elevation vulnerable to future sea-level rise

Chapter 4

Los Angeles–San Diego

Kenneth C. Topping

Southern California has a significant water problem that is difficult to solve, and it is getting worse. Since the early twentieth century, rapid growth has been enabled by water brought from distant places through nearly 1,000 miles of canals and tunnels. More than 21 million residents in the region now rely substantially on imported water for their daily needs (figure 4.1). Southern California has long exploited remote water sources, but recent lawsuits have impeded the extent to which the region may continue to draw on them.

At the same time, climate change is diminishing these water supplies, together with the long-term sustainability of the entire region. Oceanic and atmospheric warming is altering the water cycle, bringing early snowmelt, and leading to less water storage in distant mountain ranges. Floods and droughts are both more frequent and more intense. Longer-lasting heat waves coupled with declining precipitation increase the frequency of wildfires, which in turn call for adequate water supplies and pressure to combat them. Sea level rise is necessitating redesign and replacement of coastal infrastructure systems.

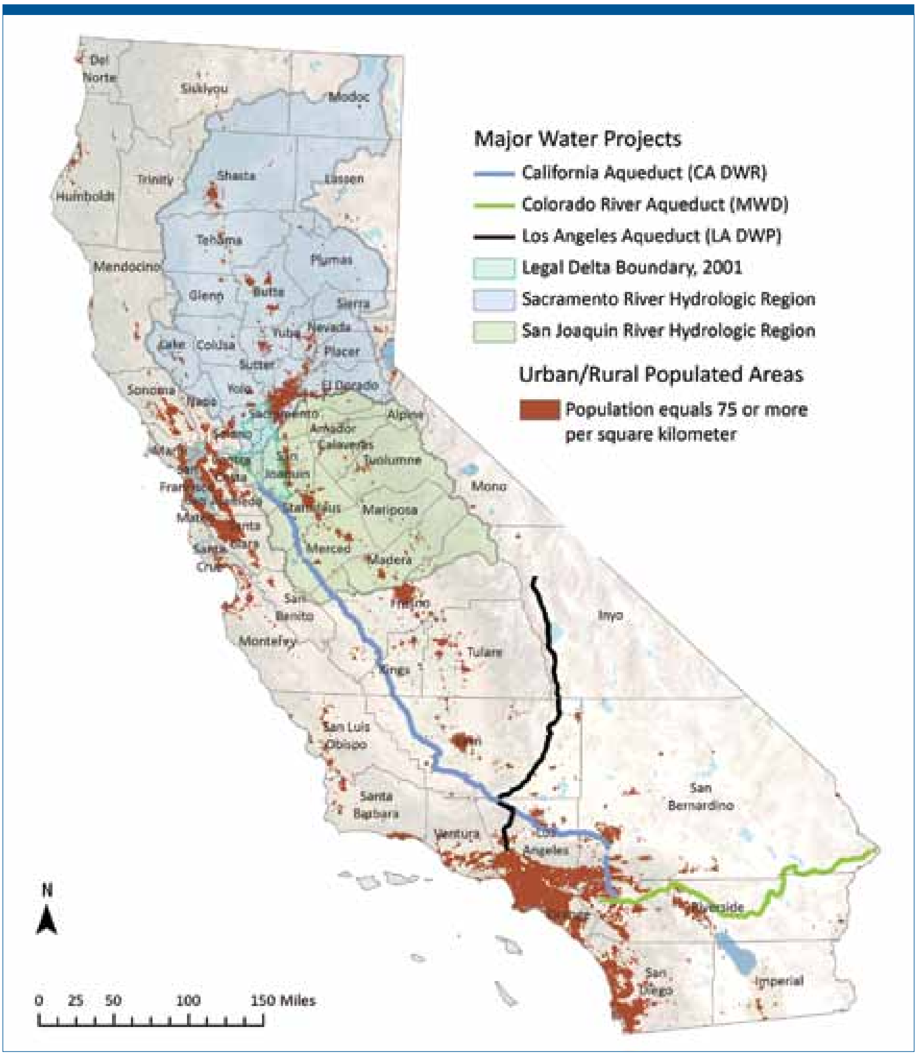
Two-thirds of California's water supply originates in the northern third of the state, but the majority of the state's population resides in the southern third, which relies on regular deliveries from the Los Angeles Aqueduct, Colorado River Aqueduct, and State Water Project to meet basic water needs. Figure 4.2 shows the complex system of federal, state, and locally sponsored canals, pipelines, and tunnels that move water among regions both within and beyond California.

Although California has a wide variety of climatic and biotic zones, much of the state's natural water supplies are declining. According to the *2009 California Climate Adaptation Strategy* (CAS), released in December 2009 by the California Natural Resources Agency:

> California must change its water management and uses because climate change will likely create greater competition for limited water supplies needed by the environment, agriculture, and cities. The state's water supply system already faces challenges to provide water for California's growing population. Climate change is expected to exacerbate these

Figure 4.2 California's Major Water Projects

Source: ORNL LandScan2007™/UT-Battelle, LLC 2005–2007; American Community Survey (ACS) 3-year estimates and 2000 U.S. Census County Division (CCD); California Dept. of Water Resources; California Dept. of Fish and Game; ESRI Data & Maps. Prepared by Carol Schuldt, California Polytechnic State University.



challenges through increased temperatures and possible changes in precipitation patterns. We can expect to experience more frequent and larger floods and deeper droughts.... Planning for and adapting to these simultaneous changes, particularly their impacts on public safety and long-term water supply reliability, will be among the most significant challenges facing water and flood managers this century. (CNRA 2009, 7)

As climate change threatens to diminish external water supplies serving Southern California, major adjustments will be needed to address future water and land use planning and to modify the region's water production and consumption practices substantially. Major adjustments will also be needed to adapt to intensified impacts of natural hazards such as earthquakes, floods, and wildfires, as well as the relatively new phenomenon of sea level rise. Unless future planning is focused on both climate change mitigation and adaptation, the potential for catastrophic consequences is likely to grow. To understand this challenge in greater depth, we examine how this region grew and the nature of its existing water sources and uses.

Historical Growth Factors

Since the founding of Los Angeles in 1781, Southern California has grown rapidly into a sprawling megaregion covering thousands of square miles that are framed by the Pacific Ocean and several mountain ranges and spill into nearby deserts. During successive cycles of population growth before and after World War II, Los Angeles symbolized the farthest reaches of westward migration in the United States. Now, with more than 21 million residents, Southern California owes its size and dynamic growth to a variety of complex factors, the most important of which has been its ability to import water over long distances.

Before 1848, when California became a state, a series of land grants from the Spanish crown had shaped the broad outlines of the region's early development. Used initially for ranching, these land holdings later formed the boundaries for subdivisions promoted by speculators marketing land to eager buyers from the East and Midwest, who were seeking healthier, more comfortable living in Southern California. Factors fueling this historic growth over the last two centuries include:

- an abundance of developable land;
- a temperate Mediterranean climate;
- arrival of the railroads and the regional streetcar system;
- marketing of Los Angeles as an ideal destination for westward migration;
- aggressive development of roads, railroads, ports, and airports; and
- importation of water from other regions.

In the late nineteenth and early twentieth centuries, Los Angeles flourished as a fledgling settlement, growing from a population of about 5,000 in 1890 to more than 100,000 by 1900. Through the early efforts of prominent figures, such as Phineas Banning, railroads continued to expand, and later they influenced development of a port at Wilmington, next to Long Beach. Large-scale rapid growth was also triggered by development of a regional electric streetcar system started by Henry Huntington in 1901. This Red Car system ultimately included more than 1,000 miles of track extending from downtown Los Angeles to San Pedro, Torrance, Long Beach, Santa Monica, Pasadena, San Bernardino, Fullerton, and other corners of the region. The streetcar system sparked real estate development around widely scattered small town centers that served citrus and other agricultural industries. When it became apparent that this growth might eventually outstrip the natural water supply, efforts were initiated to bring water over hundreds of miles from other regions through aqueducts. Prominent among these were the Los Angeles and the Colorado River Aqueducts.

Los Angeles Aqueduct

Major water management efforts in the early 1900s were led by Los Angles real estate interests, including the *Los Angeles Times'* publisher Harrison Gray Otis, to promote a bond election to fund transport of water from the Owens River, some 215 miles away. Following a campaign that publicized the possibility of imminent drought, voters in 1905 authorized $2.5 million for purchase of Owens Valley water rights. A second election in 1907 authorized $23 million for construction bonds (Carle 2000). Led by water system superintendent William Mulholland, the city built an aqueduct to bring water from the Owens River to a large reservoir in the northern San Fernando Valley and then to other parts of the city through the Los Angeles River (figure 4.3). Easements granted by Congress for the aqueduct's passage over federal lands permitted construction of the first segment, which was completed in 1913 (City of Los Angeles 1916).

Construction of the Los Angeles Aqueduct helped create the market conditions to encourage extensive investments in agricultural and residential development and further expand the city's boundaries and population. By 1920, the city reached 576,000 residents, surpassing the population of San Francisco for the first time.

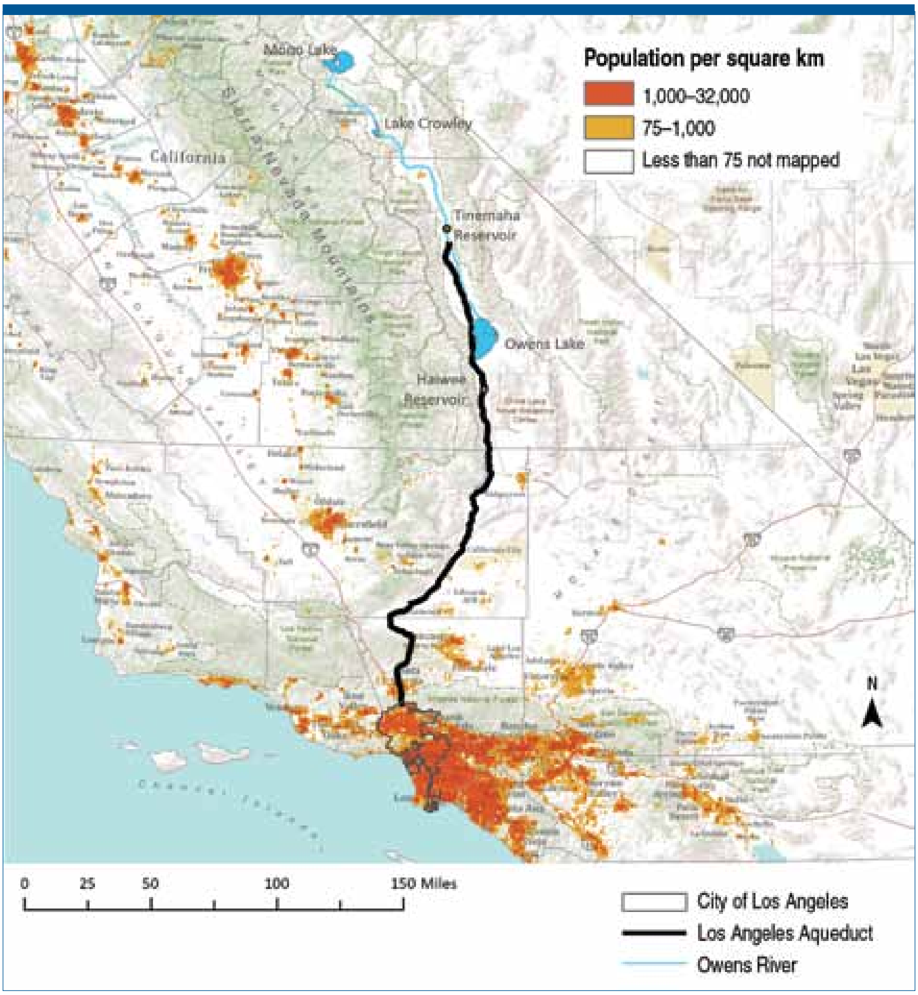
In 1930 California voters approved a $40 million bond issue authorizing the purchase of expanded land and water rights in the Owens River Valley and construction of the Mono Basin Aqueduct, which extended the project to Mono Lake, 280 miles from the city. Diversions of water from Mono Lake streams began in 1941, and by 1970 groundwater pumping and Mono Basin diversions increased to fill this second aqueduct. The history of aqueduct development was rife with conflicts between Los Angeles and Owens Valley interests. In 1972, Mono County filed a lawsuit against Los Angeles, but it eventually stalled, and additional pumping of the groundwater basin by the city was halted (Carle 2000; Erie 2006; Sauder 1994).

The Colorado River Aqueduct

Completion of the Los Angeles Aqueduct helped the city, but the problem of providing water to outlying areas remained unaddressed. Rejecting the idea of

Figure 4.3 The Los Angeles Aqueduct

Source: ORNL LandScan2007™/UT-Battelle, LLC 2005–2007; American Community Survey (ACS) 3-year estimates and 2000 U.S. Census County Division (CCD); LA County Dept. of Regional Planning; California Dept. of Water Resources; ESRI Data & Maps. Prepared by Carol Schuldt, California Polytechnic State University.



annexation into Los Angeles, a group of about 250 delegates from 38 cities and communities formed the Colorado River Aqueduct Association in September 1924. Legislation was introduced in 1925 and passed in 1927 to form the Metropolitan Water District of Southern California (MWD). The district was incorporated in 1928, after voters in 11 cities decided to join the new district. The number of members grew to 13 cities by 1931 (O'Connor 1998). A $220 million construction bond was approved by voters in 1931, and by 1941 the 242-mile Colorado River Aqueduct was completed, allowing water deliveries to begin (figure 4.4).

Until the 1940s the MWD was comprised solely of cities, but after World War II most new members were municipal water districts. It grew to include

Figure 4.4 Metropolitan Water District of Southern California (MWD) Boundary and the Colorado River Aqueduct

Sources: MWD; California Dept. of Forestry and Fire Protection (CAL FIRE); ESRI. Prepared by Carol Schuldt, California Polytechnic State University.

27 member agencies in six counties: Los Angeles, Orange, Riverside, San Bernardino, San Diego, and Ventura. The primary source of revenue for the MWD was a property tax included in the authorizing legislation. Although initially influenced by the City of Los Angeles, the MWD's governance eventually shifted to a wide-ranging mix of elected and appointed directors who held varying allocations of votes (O'Connor 1998).

Due to its instrumental role in providing supplemental water to Southern California, the MWD became a powerhouse in land development. By 1950, the City of Los Angeles population was just under 2 million, halfway to its present level of 4 million. By 1970, Los Angeles, Orange, San Diego, and Ventura Counties had tripled their combined population to a total of 10 million, nearly half of the region's present count. Between 1984–1985 and 1994–1995, the MWD average annual use of water directly delivered to member agencies increased by nearly 1.8 million acre feet. Top users included the San Diego County Water Agency (496,815 acre feet); City of Los Angeles (238,474 acre feet); and Municipal Water District of Orange County (208,434 acre feet) (O'Connor 1998, 12–13). By 1999, the MWD was providing 60 percent of the water used by nearly 18 million people living in coastal counties, from Ventura to San Diego, including 27 water agencies and 127 cities (Carle 2000; Erie 2006).

State Water Project

It became evident in the 1950s that continued growth would require additional water deliveries to supplement the Los Angeles and Colorado River Aqueducts. At the urging of the MWD and other Southern California interests, the state legislature passed the Burns-Porter Act, which authorized a $1.75 billion bond issue to construct the State Water Project (SWP). This bond would be used to implement a major north-south transfer of water via San Francisco Bay and the Sacramento–San Joaquin River Delta, including multiple reservoirs and conveyance systems.

In 1960, California voters approved a ballot measure ratifying the Burns-Porter Act. Construction of the first major section of the SWP was completed, and initial deliveries of water to Southern California were made in 1973. By 1997 the Coastal Branch of the aqueduct system was completed, linking the SWP to Santa Barbara and San Luis Obispo Counties. From 1952 to 2007, SWP construction costs totaled about $6.4 billion (California Legislative Analyst's Office 2008).

In 1982, legislation authorizing an $11.6 billion bond to build a canal in the delta was put on a statewide ballot through a signature petition. The proposed Peripheral Canal was designed to end the pumping of water through the delta itself by moving fresh water past tidal waters, thus delivering it more efficiently to the south. Environmentalists opposed this canal fearing alteration of delta ecosystems. The measure was defeated in June 1982 by a substantial majority (63 percent of the electorate), and it proved to be a turning point in the established trend toward ever-increasing Southern California water imports via the SWP (Carle 2000; Erie 2006).

A federal court ruling in 2007 required a reduction in water exports via the delta because the state and federal water pumping projects were placing the already endangered delta smelt at risk of extinction. To comply with the order, the state reduced pumping. In 2008 a separate court ruling stated that a U.S. Fish and Wildlife Service biological opinion related to water management operations did not adequately protect sensitive populations of fish, including salmon. This issue remains the subject of ongoing legal actions and counteractions by various interests. However, the U.S. Supreme Court on October 31, 2011, declined to hear on appeal by farmers of a lower appellate court ruling protecting the delta smelt.

These court cases highlighted the reality that two major California water delivery projects, the SWP and the federal CVP (Central Valley Project), rely on water flowing through the delta as their main source of supply. A majority of Californians rely on such water for all or part of their drinking water. Additionally, approximately one-third of the state's cropland uses water flowing through the delta (California Legislative Analyst's Office 2008).

The Role of the Federal Government

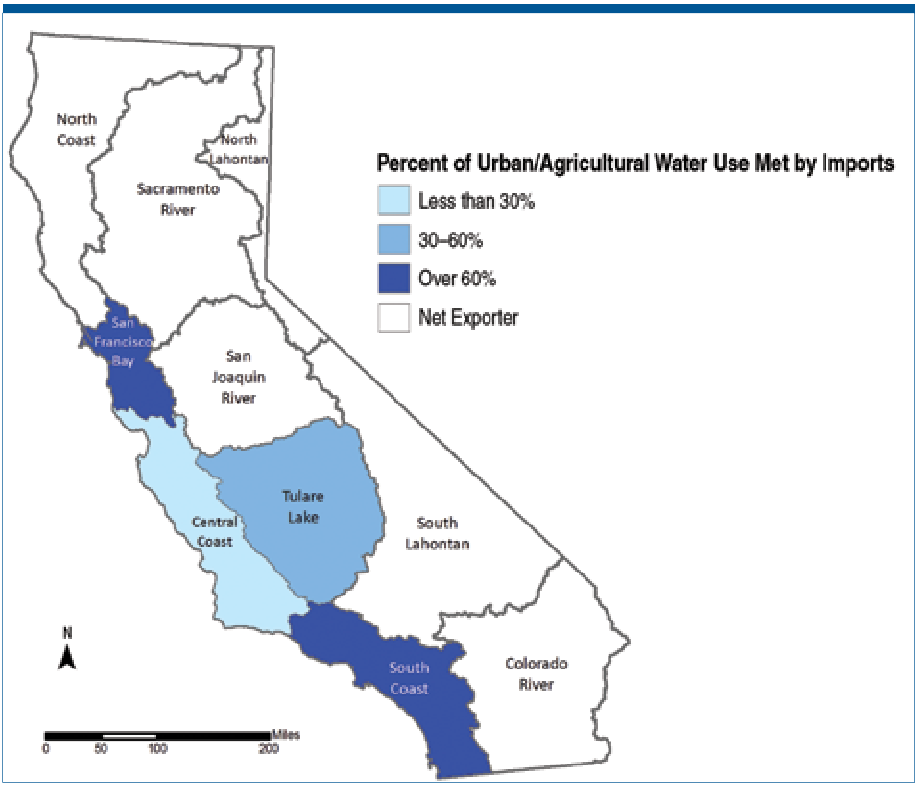
Since the beginning of the twentieth century, California's water dilemmas have grown out of ambitious water development by federal, state, and local gov-

State Water Project Aqueduct, Central Valley, California
Credit: Courtesy of California Dept. of Water Resources.

ernment agencies. Beyond Southern California, federal policy has supported importation of water to other regions, including the San Francisco Bay Area and the Central Valley. In 1913 a federal law authorized construction of the O'Shaughnessy Dam on the Tuolomne River to create the Hetch Hetchy Reservoir, which would then provide supplemental water for the City and County of San Francisco. Construction of the federally funded Central Valley Project began in the 1930s, during the Great Depression, and was completed in 1951 (Carle 2000).

As a result, the federal government now owns California's largest surface water storage capacity of nearly 17 million acre feet in 10 reservoirs on multiple river systems (California Legislative Analyst's Office 2008). Furthermore, the federal court rulings restricting SWP pumping over the past decade have led the state to reconsider the possibility of reviving the Peripheral Canal or alternate project to convey fresh water around or under the delta.

Figure 4.5 Hydrologic Region Water Use Met by Imports
Source: California Legislative Analyst's Office (2008).



Note: While the Colorado River region is a net exporter of water, its main source is imported from the Upper Colorado River Basin beyond the California state borders.

Within this broader framework, it is important to note the sources and distribution of water flowing through the delta. The largest sources are the combined inflows from the Sacramento River (74 percent) and the San Joaquin River (16 percent); the smallest (8 percent) arises from in-delta precipitation and eastern tributaries. Of the water in the delta, a relatively small portion (15 percent) is actually transported south through the SWP for urban residential and industrial use in Southern California; 12 percent is transported through the Central Valley Project; and 8 percent is used locally, mostly for agricultural purposes. Fully 65 percent flows out to Suisun and San Francisco Bay (California Legislative Analyst's Office 2008).

These ambitious water transfer projects have resulted in major urbanized regions of the state becoming dependent on imports as a primary water source. Figure 4.5 shows that more than 60 percent of urban and agricultural water use in both the San Francisco Bay and South Coast hydrologic regions is accommodated by imports from other regions. In the Central Valley, for example, from 30 to 60 percent of water in the southern Tulare Lake Hydrologic Region is imported.

Planning in Los Angeles Comes of Age

Among the prominent features of the Los Angeles metropolitan region are the film capital of Hollywood, suburban San Fernando Valley, and Los Angeles International Airport as well as the harbor, which functions in tandem with Long Beach's harbor to form the largest port complex on the West Coast. During its peak growth period, Los Angeles encompassed an area of massive proportions that dwarfed the hundreds of smaller municipalities in the region.

As automobile use expanded rapidly before World War II, serious conflicts arose between the streetcar system and road traffic. Following the war, in conjunction with the early nationwide development of the interstate highway system, major public investments were directed to freeway systems. These transportation changes drew users away from the Red Car system, and the last streetcar line closed in the early 1960s. Although a new rapid transit rail system emerged in the 1980s to connect downtown Los Angeles with some suburban centers, freeways remain the dominant mode of transport throughout the sprawling metropolitan region.

Prior to World War II, Los Angeles had no citywide zoning to regulate development. Basic zoning was established in 1946 to control height, bulk, and setbacks of buildings on property as well as allowable floor area. No comprehensive plan was in place for the city, however. During the 1960s and 1970s, a complex planning system emerged when the city's planning department conducted a citywide goals program. For the first time, a citywide plan was prepared, approved by the mayor, and adopted by the 15-member city council. The new general plan featured a centers concept that sought to steer growth into high-intensity, mixed-use concentrations linked by a proposed rail-transit system. Other citywide general plan elements eventually addressed housing, open space, various infrastructure facilities, and public safety.

Because the general plan was formulated after adoption of basic zoning, in the early 1980s widespread contradictions regarding the greater intensity of development allowed under zoning than under the general plan had become evident. The build-out capacity of the 1946 zoning ordinance would accommodate 10 million people, whereas the general plan restricted the population level at build-out to around 4 million.

A lawsuit was brought by residents who were angered by high-rise office buildings that, while consistent with commercial zoning, were constructed in areas designated as single-family residential zones by the general plan. Following a successful judgment in favor of the homeowners, the entire city was rezoned in the late 1980s using geographic information systems (GIS), which helped bring zoning into conformity with the general plan. Meanwhile, during the boom of the 1980s, building permits were issued for more than 40 million square feet of office space, and the skyline began to change shape again. The city initiated preparation of a new general plan framework in 1990, and it was adopted in 1996. This framework incorporated the earlier

Metro Rail Station Development, Del Mar Station, Pasadena
Photograph courtesy of Metro. ©2011 LACMTA.

centers concept as a series of targeted growth areas that took into account a variety of urban forms beyond high-rise centers. Construction continued and led to the arrival of Walt Disney Concert Hall, the emergence of a viable downtown office-residential core, and expansion of subway, light rail, and bus systems that connected downtown with various suburban communities.

During this same period, cities and counties throughout Southern California were bringing their planning procedures into closer alignment with an environmental awareness that had been growing since the 1970s when California planning laws were updated with new requirements for local general plans and their implementation. By the 1990s interest was intensifying in the concept of smart growth, which emphasized a more balanced, regional pattern featuring revitalization of existing town centers through combined mixed-use and transit development. A closer relationship was emerging between local land use, transportation, and environmental planning.

Regional Growth

The first decades of the twenty-first century continue to see massive growth in the Los Angeles region. Planning for certain designated aspects of growth is coordinated at the regional level by the Southern California Association of Governments (SCAG), a joint metropolitan planning organization (MPO) and a council of governments (COG) under federal and state laws. The region

Table 4.1 Top Five California Growth Counties, 2000–2009

Source: State of California (2009).

County	Population Change	Rank Within State
Los Angeles	832,911	1
Riverside	568,392	2
San Diego	372,182	3
San Bernardino	342,325	4
Orange	291,796	5
Total Top Five Counties	2,407,606	

Table 4.2 Population of SCAG Regional Counties, July 2009

Source: State of California (2009).

County	Population
Los Angeles	10,409,035
Orange	3,115,393
Riverside	2,127,612
San Bernardino	2,064,375
Ventura	841,001
Imperial	179,254
Total Population	18,736,670

Table 4.3 Population of MWD Counties, July 2009

Source: State of California (2009).

County	MWD
Los Angeles	10,409,035
San Diego	3,208,466
Orange	3,115,393
Riverside	2,127,612
San Bernardino	2,064,375
Ventura	841,001
Total Population	21,765,882

included in SCAG encompasses 38,000 square miles, including 6 counties and 189 cities together with many unincorporated communities. It is divided into 14 subregions for coordination purposes.

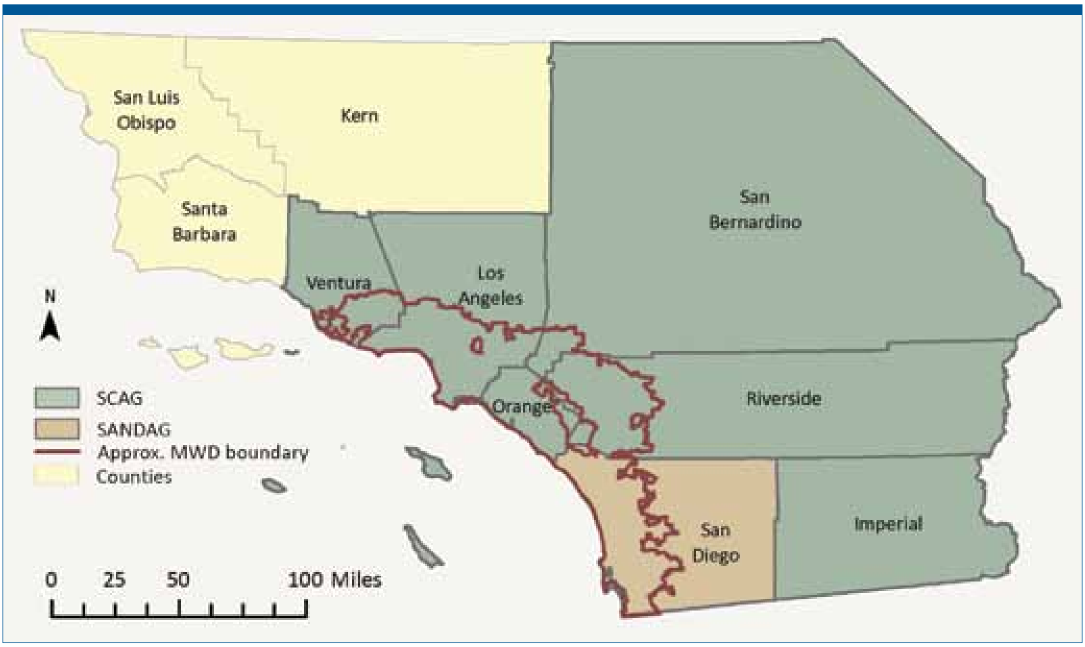
The SCAG region's population in 2009 was estimated at 18,736,600, or nearly 49 percent of California's total population of 38,487,900; the city of Los Angeles alone had an estimated population of 4,066,000 (State of California 2008). With a land area of 485 square miles, the city dominates the region's landscape. Urban geographers have identified it as one of ten "alpha level" world cities, based on the presence of global service centers for major urban economic sectors including accounting, advertising, banking, and legal services (Beaverstock, Smith, and Taylor 1999).

Recent growth has taken two forms. On the one hand, higher-density housing and mixed-use developments are being constructed near subway, light-rail, and express bus stations as well as lines in new urban clusters located near existing town centers. Such siting provides convenient and varied living, working, shopping, and cultural environments. By contrast, leapfrog suburban development continues to intrude into agricultural areas, such as extensive new subdivisions encroaching on the San Bernardino County Dairy Preserve—often called the Chino Ag Preserve—and other areas of the Inland Empire, a subregion of San Bernardino and Riverside Counties.

Between 2000 and 2009, population growth in Southern California, including San Diego County, exceeded 2 million people, and much of this growth took place in inland valleys, away from the Pacific coast. All five of California's

Figure 4.6 SCAG, MWD, SANDAG Areas

Source: SCAG; SANDAG; MWD; CAL Fire; ESRI. Prepared by Carol Schuldt, California Polytechnic State University.



top-ranked growth counties were in Southern California, four of which fall within the SCAG region (table 4.1). San Diego County has its own county-level regional planning agency, the San Diego Association of Governments (SANDAG), but it largely falls within the MWD service boundary and ranks third in statewide population growth. It experienced an increase of nearly 400,000 residents between 2000 and 2009, which brought its total to more than 3 million.

Tables 4.2 and 4.3 compare the populations of the overlapping SCAG and MWD regions, and figure 4.6 shows the primarily coastal area serviced by MWD, including 14 cities, 12 municipal water districts, and the county water authority. The MWD boundaries are not coterminous with county lines, but most residents of the six SCAG counties served by MWD live within its boundaries. The population in the seven counties that comprise MWD's primary service area now totals more than 21 million, or 55 percent of California's population. While the Antelope Valley and Imperial Valley desert subregions are formally outside MWD service boundaries, they also rely on imported water from the SWP and the Colorado River Aqueduct.

Climate Mitigation, Adaptation, and Action Plans

Nationally, California has taken an active lead in addressing climate change. In June 2005 then-governor Arnold Schwarzenegger led a vigorous and widely publicized policy initiative to mitigate global warming through Executive Order S-03-05, which established the following greenhouse gas (GHG) emission reduction targets: by 2010, reduce to year-2000 emission levels; by 2020, reduce to 1990 levels; and by 2050, reduce to 80 percent below 1990 levels.

This order was followed by passage of Assembly Bill (AB) 32, the California Global Warming Solutions Act (2006). It charged California's Air Resources Board (ARB) with executing a comprehensive program to achieve quantifiable, cost-effective GHG emissions reductions of 25 percent by 2020 through development of regulations and market mechanisms under California Health and Safety Code Section 38500. In 2008, Senate Bill (SB) 375 identified a regional target-setting process for GHG emissions reductions in California, calling for ARB to release draft targets by 30 June 2010 and for each MPO to develop a sustainable communities strategy (SCS) that identifies how ARB's GHG reduction targets would be met within regions. Although local land use planning is not directly the subject of the bill, regional target-setting processes will impinge on local development decisions, and ultimately will have the effect of strengthening the role of MPOs and other regional planning organizations.

Parallel to these efforts are the outcomes of lawsuits against San Bernardino and Stanislaus Counties that were filed by Jerry Brown, California's attorney general at the time and now its governor. In those suits, the state held the position that the respective county's general plans did not honor the emission reduction strategies of AB 32. Using the California Environmental Quality Act (CEQA) as a base, successful settlements required the two counties to include GHG emissions reduction policies and actions in their new general plans. Subsequent changes in CEQA guidelines have reinforced the settlements' outcomes, leading to a spate of local city and county climate action plans that seek to avoid such lawsuits by integrating climate change mitigation.

The State of California Multi-Hazard Mitigation Plan states the following:

> Climate change is already affecting California. In addition to changes in average temperatures, sea level, and precipitation patterns, the intensity of extreme weather events is also changing. Extreme weather events, such as heat waves, wildfires, droughts, and floods, are likely to be some of the earliest climate impacts experienced. In order to address these changes, California has developed a variety of laws, policies, and programs to both mitigate (or reduce) the emission of greenhouse gasses into the atmosphere and adapt to the changes that will take place. (Cal EMA 2010, 103)

California's Climate Adaptation Strategy (CAS) released by the California Natural Resources Agency in 2009 also stresses the need for public policy that addresses long-term climate change impacts identified by the Intergovernmental Panel on Climate Change, such as severe storms, flooding, water and food shortages, and desertification of temperate regions.

A question addressed at some length in the CAS is the appropriate relationship between climate mitigation and adaptation actions. To some degree, regional GHG emissions reduction (mitigation) resulting from MPO efforts throughout the state will help moderate the intensity of climate change globally. Yet a concern remains regarding adaptation actions that can be taken regionally to help create societal resilience to climate change impacts that may be inevitable and possibly irreversible, but are beyond the immediate reach of mitigation efforts.

Adaptation Strategies

One major adaptation strategy necessary for Southern California is recognizing the long-term reductions in water resources induced by intermittent droughts and other conditions that create water shortages. The multiple challenges to be addressed include diminished water supply, water conservation, water reclamation, planning and governance, and natural hazard mitigation.

Water Supply

During the past two decades, Southern California has experienced several droughts when SWP flows were diminished by lowered reservoir storage. The State of California Multi-Hazard Mitigation Plan addresses this issue.

> Droughts exceeding three years are relatively rare in northern California, the source of much of the state's water supply. California's last major statewide drought was in 2007–2009. At a regional level, parts of southern California experienced a series of consecutive dry years in the late 1990s/early 2000s, with water year 2002 setting records for the single driest precipitation year in cities such as Los Angeles and San Diego. The Colorado River Basin, an important source of water supply for southern California, experienced five consecutive years of drought in water years 2000–2004. (Cal EMA 2010, 313)

In 2007, California was entering a drought formally recognized in 2008 by the governor's Executive Order S-13-08. Dr. Renée Kidson, chief hydrologist for water accounting in the Australian Government Bureau of Meteorology, has chronicled the impacts of drought-based fluctuations on water deliveries from the SWP and Colorado River Aqueduct. In light of climate change, she suggests that alternative sources of water will be needed, stating that although MWD had a maximum contracted supply of 2,011,500 acre feet of SWP water, this volume was met only once, in 2006, during the period from 2001 to 2008 (Kidson 2009). Noting that MWD is the largest supplier of municipal water in the world, its deliveries were less than 40 percent of ordered volumes in two of those eight years—2001 and 2008 (table 4.4).

Table 4.4 Acre Feet (AF) of Water Requested and Granted, 1996–2008
Source: Kidson (2009).

Year	MWD Requested (AF)	SWP Granted (AF)	% of Request Granted
1996	738,800	738,800	100
1997	1,044,100	1,044,100	100
1998	1,203,578	1,203,578	100
1999	1,180,000	1,180,000	100
2000	1,507,136	1,507,136	100
2001	2,011,500	784,485	39
2002	1,800,107	1,408,060	78
2003	2,011,500	1,810,350	90
2004	2,011,500	1,307,475	65
2005	1,911,500	1,720,350	90
2006	1,911,500	1,911,500	100
2007	1,911,500	1,146,900	60
2008	1,911,500	669,025	35

Kidson's analysis highlights the three primary factors affecting the SWP's diminishing ability to ensure water deliveries: drought; pumping constraints arising from provisions of environmental lawsuits that restrict pumping from the delta; and agencies' placements of larger orders (Kidson 2009). Furthermore, the contracted supply of Colorado River Aqueduct water, which includes a fixed base allocation of 550,000 acre feet per year and a variable surplus allocation of up to 662,000 acre feet, is not reliable either. Kidson concludes that to secure a reliable water supply for expected levels of development for the year 2020, the MWD should reduce its reliance on imported water, increase conservation, and develop alternative sources.

In a broader assessment, Stephen Erie (2006) evaluated factors affecting projected water deliveries to the year 2050, concluding that it will be necessary for the MWD to rely more on water conservation and development of local supplies to meet regional growth demands at the same time as it offsets probable reductions in external water supplies. Projections for demand in 2025 suggest that the MWD will need to supply from 2.4 to 2.7 million acre feet of water.

Water Conservation

Throughout its history, land use in Southern California has been characterized by development that requires large amounts of water, including large-lot, single-family homes, golf courses, and irrigated agriculture. The region's Mediterranean and desert climates have made extensive watering of lawns and gardens standard practice. Many cities still enforce landscape requirements that emphasize cosmetic uniformity.

This attitude began to change with the onset of a major drought in the late 1980s. Tom Bradley, then mayor of Los Angeles, appointed a Water Conservation Task Force in 1988. Cochaired by the city's planning and public works directors, the task force's water conservation recommendations, such as installation of low-flow toilets, related principally to new development. Many of the recommendations were implemented, and the effort also led the planning department to prepare and issue guidelines that homeowners could implement themselves. For example, xeriscape techniques, which use less water than those for traditional lawns and gardens, were encouraged for residential landscaping. The city has implemented other measures to encourage water conservation, and together they have substantially reduced per capita water consumption.

Nevertheless, water conservation efforts in Southern California have barely scratched the surface. Among the implemented water-saving practices are:

- expanded and vigorous xeriscape promotion on a community-wide and regional scale;
- sanitary capture of washing machine and shower "grey water" for home landscape use;
- creation of porous driveway and road coverings to facilitate water percolation rather than run-off;
- greater use of basins for water detention (to slow runoff) and retention (for stormwater capture and percolation into the groundwater); and
- for proposed subdivisions, water-use audits that identify practical water-saving conditions for development as part of environmental review and mitigation monitoring processes.

Since these practices can be implemented most easily in new developments, several California laws bring the issue of water supply to the forefront. Under SB 610, passed in 2001, as a condition of approval of new subdivisions of 500 homes or more a reliable water supply is required. SB 221, adopted the same year, requires water supply assessments for developments identified as projects under CEQA guidelines, many of which have fewer than 500 housing units. Additionally, under Water Code Section 10632, urban water suppliers, such as cities and special districts, must prepare urban water management plans that include a contingency analysis for implementation in case of an urban water shortage. It must identify actions needed to prepare for and respond to a catastrophic interruption of water supplies, such as could occur during a regional power outage, earthquake, or other disaster.

The water conservation challenge for existing communities lies with the application of creative incentives, such as tiered rates, which increase user charges on a logarithmically increasing scale for heightened water use, as well as pursuit of grant-funded water conservation projects.

Water Reclamation

New local forms of water supply also will be needed to offset future reductions of water imports. With diminishing deliveries of SWP and Colorado River water anticipated over time, the MWD and member agencies need to pursue investigations of water reclamation techniques, such as desalination and recycling tertiary treated wastewater. Presently, wastewater recycling is used in Orange County, for example, and it offers promise for other regions where thick sedimentary layers between the surface and groundwater aid in the filtering process.

In the long term, seawater desalination is even more promising for the coastal MWD region. Unit costs currently remain high in comparison to other water supplies due to heavy energy requirements, however. The desalination process also raises the cost to the environment from extensive GHG emissions, although companion solar installations may help with mitigation. Simple gravity also exacerbates the cost issue, since seawater desalination requires pumping the water inland and uphill, as does the need to develop additional reservoir capacity to store water at intermediate distances.

Several California communities, including Marina, Morro Bay, and Port Heuneme, already use desalinated seawater. With the help of the U.S. Army Corps of Engineers, plans are progressing for a desalination facility for the small resort village of Cambria, where the water supply from two local creeks is constrained by competition between agricultural and town uses. Another environmental concern to be overcome during development of desalination systems is the management of intake and outflow to avoid adverse impacts on sea life. One option is to bury intake and outflow systems beneath beach sands in areas with sufficient depth and porosity.

Neither reclamation nor desalination alternatives will be inexpensive or easy. Development of new local supplies through increased reclamation will require major investments, yet it promises to offer substantial benefits over time through wide-scale development and implementation.

Planning and Governance

The overlapping boundaries of SCAG and MWD belie their functional and symbolic differences in governance. Functionally, under federal law SCAG is an MPO, and its primary focus is on transportation planning; the MWD, however, is a regional special district concerned primarily with water purchases, delivery, and management.

SCAG is responsible for advising state and federal transportation agencies and its member organizations on issues of highway improvements and vehicular movements in Southern California. Traditionally, it has been oriented to advocate for relatively minor adjustments to the vast network of freeway and road improvements, thus facilitating sprawl and reliance on the automobile as the principal mode of personal transportation. Now, under SB 375, SCAG is tasked with setting GHG emissions reduction targets that ultimately will have the force of law through the CEQA and ARB.

As a facilitator of transportation management, SCAG will have to adjust its former focus on the automobile and begin to promote greater investments in rail transit and smart growth land use modifications to lower GHG emissions through reduced per capita vehicle miles traveled. It will need to facilitate and support a more diversified transportation and land use mix to meet these objectives. One aspect of this change in focus is SCAG's recent effort to encourage high-speed rail and expand other forms of mass transit that offer viable alternatives to highway travel.

This need for transport diversity is recognized in a SCAG (2009) publication that examines various climate change topics, including weather impacts, peak oil, land use planning, green building, education, governance and finance, and sustainability. However, the only essay in the report that identifies water as a serious, long-term issue is by Dan Cayan (2009, 7), who observes:

> In one form or another, many of Southern California's climate concerns radiate from efforts to secure an adequate fresh water supply.... Of all the areas of North America, Southern California's annual receipt of precipitation is the most volatile—we only occasionally see a "normal" year, and in the last few we have swung from very wet in 2005 to very dry in 2007 and 2008.... Southern California has special challenges because it is the most urban of the California water user regions and, regionwide, we import more than two thirds of the water that we consume.

The MWD has been challenged throughout its history to balance issues of governance (such as its arcane system of voting) with the needs of individual member agencies. Another key governance issue is whether the MWD is to be the sole supplier of supplemental water in the region (O'Connor 1998). While the MWD has exercised leadership in assessing and promoting water conservation and reclamation measures, primarily in relation to drought management, on behalf of its members, it has yet to deal fully with the issue of permanently reducing the external water resources from which it supplies supplemental water to its members. It now seems apparent that, in addition to drought management, the MWD must address the long-term reduction of water supply touched on in Cayan's essay and elaborated in the California Climate Adaptation Strategy (CNRA 2009).

With regard to climate change, the governance issues facing the MWD and SCAG are quite different. While law mandates SCAG to address climate mitigation through reduction of GHG emissions, the MWD must deal directly with climate adaptation challenges posed by permanently reduced external water sources. In light of shrinking external supplies, overriding the MWD concerns include what direct responsibility it should take for regional water conservation and what actions it should promote among member agencies in order to reduce per capita water use.

Despite the need for coordination, no substantive relationship appears to exist between SCAG and the MWD that assists in executing their separate regional governance functions. Yet some formal linkage must be established to avoid long-term conflicting outcomes from the MWD's traditional water policies, which tend to foster centrifugal regional development, and SCAG's fledgling efforts to promote more compact growth.

Natural Hazard Mitigation

An aspect of climate change that needs closer scrutiny is the intensification of natural hazards, such as flooding, wildfires, heat waves, and coastal inundation associated with sea level rise. This concern was foreshadowed in the 2007 State of California Multi-Hazard Mitigation Plan.

> It is now clear that in coming decades natural disasters are broadly expected… to intensify due to climate change. Emergency managers, planning agencies, private companies, and communities especially affected by climate change will be challenged to adapt their planning to take into account an increasing array of related natural hazards. Disasters expected to be more widely experienced in the future include: avalanches, coastal erosion, flooding, and sea level rise; extreme heat and prolonged drought; mudslides and landslides; severe weather and storms; and wildlands fires. (OES California 2007, 134)

Hazard mitigation planning in the United States is legislated under the Disaster Mitigation Act of 2000, which requires the Federal Emergency Management Agency (FEMA) to approve multihazard mitigation plans as a precondition for state and local eligibility to receive federal mitigation project grants. By 2009, FEMA had approved nearly 19,000 local mitigation plans prepared by cities, counties, and special districts across the country. Similar to the general plan safety elements required by California planning law, these plans deal with hazard and risk identification, assessment, and mitigation action proposals to prevent disaster losses before they happen. Mitigation actions may involve modification of development to redirect it away from hazardous areas—such as any 100-year floodplains shown on federal flood insurance rate maps or state-identified Wildland-Urban Interface (WUI) areas—and toward those most suitable for growth or urban intensification.

Diminished long-term water supply can intensify the risks and impacts of catastrophic fires in WUI areas. According to the 2010 State of California Multi-Hazard Mitigation Plan (Cal EMA 2010), from 1950 to 2008 most wildland fires occurred in hilly and mountainous areas, particularly near populated regions of Southern California, and in the past decade a series of devastating wildfires burned WUI areas. In October 2007, wildfires displaced nearly one million residents, taking 10 lives, and destroying thousands of homes. The 2007 fire siege highlighted the well-recognized fact that fire, an integral component of Southern California's ecosystems, can have cascading consequences. The Station Fire in August and September 2009 occurred in national forest lands near the city of La Canada Flintridge and resulted in loss of substantial watershed ecosystems and mudflows in suburban neighborhoods. These events led to re-examination of wildland fire management practices near urban areas.

> Larger and more frequent wildfires will impact California's economy by increasing fire suppression and emergency response costs, damages to homes and structures, interagency post-fire recovery costs, and damage to timber, water supplies, recreation use and tourism. The California Department of Forestry and Fire Protection (CAL FIRE) spent over $500 million on fire suppression during fiscal year 2007/2008. As climate change continues these costs are expected to increase. (CNRA 2009, 111)

Sea level rise, another climate change–related hazard in Southern California, leads to coastal flooding, permanent inundation, wetland loss, habitat degradation, increased coastal erosion, and saltwater intrusion into freshwater aquifers as well as ocean acidification. By 2100, the replacement value of buildings and contents (not including land value and relocation costs), in areas that are vulnerable to a 100-year coastal flood with 1.4 meters of sea level rise is forecast at approximately $24.8 billion for four coastal counties (Los Angeles, Orange, San Diego, and Ventura) (CNRA 2009). During the remainder of the twenty-first century, reengineering of coastal infrastructure such as highways, drainage systems, and wastewater plants will be required to avoid substantial losses due to sea level rise.

Seismicity, while not related to climate change, is also of great concern to the region. As highlighted by the March 2011 earthquake and tsunami in Japan, a catastrophic event in Southern California is a major mitigation concern. Earthquake-induced water, oil, and gas pipeline breakages could lead to widespread fires in urban areas, and due to the outdated design and deteriorating condition of existing systems, the impacts on water systems are potentially severe. In the 2008 Great Southern California ShakeOut earthquake scenario exercise undertaken by the U.S. Geological Survey, the city of Los Angeles and nearby communities documented serious, long-term outages for water delivery systems. A catastrophic earthquake is an event that seismologists anticipate will occur in the region within the next several decades (Cal EMA 2010). Scawthorn, Eidinger, and Schiff (2005) documents the need for greater attention to potential blockages of response and recovery efforts, especially in urban areas where water systems are damaged, destroyed, or disrupted by seismic events.

Hazard mitigation initiatives cannot be managed efficiently on a local government level alone. For greatest effectiveness, they should be addressed at a regional level, but in Southern California, SCAG and the MWD have shown little interest in such efforts, even though both entities share a common goal of mitigating natural hazards as threats to their respective primary transportation and water delivery concerns.

Toward a Regional Resource Management Authority

Climate change will have a profound influence on the Southern California region and will alter trends previously assumed to be constant. Understanding relationships between climate action and adaptation is key to effective planning for future water, growth, transportation, and environmental sustainability. As with most other significant physical and environmental adjustments, interrelated social, economic, and institutional changes are needed to redirect political will. Southern California provides a living laboratory for learning about success and failure in planning, governance, resource management, and natural hazard mitigation on a megaregional scale. A major question is whether important lessons can be learned soon enough to redirect the future toward greater sustainability.

SCAG, the MWD, and SANDAG possess shared interests in coordinating outcomes for meeting future water delivery, growth, transportation, and hazard mitigation needs. Yet no formal or legal mandate exists to coordinate these functions regionally. This governance vacuum remains a barrier to comprehensive regional action on climate change. To fill this vacuum, the California legislature should pursue consolidation of SCAG, MWD, and SANDAG into a single regional resource management authority (RMA) for Southern California. This authority would retain the principal existing powers of the three agencies, and legislative authorization to coordinate regional climate mitigation and adaptation actions would be added.

The consolidated entity would have additional taxing, investment, and regulatory powers beyond those possessed by its three member groups, and be responsible for the following specific sectors.

- **Growth and transportation:** Review and adjust SCAG and SANDAG growth projections, transportation plans, and SB 375 sustainable growth plans to synchronize them with modified water supply, conservation, and reuse projections.

- **Water:** Review and adjust MWD water use projections and allocations to make them consistent with regional growth projections, transportation plans, and SB 375 sustainable growth plans and regional water conservation and reuse goals.
- **Regulation:** Intervene in regional and subregional disputes over water, growth, and transportation plans and offer formal mediation by an administrative law judge for their resolution.
- **Infrastructure taxing and loan authority:** Raise revenues and undertake focused projects to further regional and subregional water conservation and reuse, green energy, and hazard mitigation goals.

No such organization currently exists in California, although there are parallels in the Tahoe Regional Planning Agency (interstate), San Francisco Bay Conservation and Development Commission, Delta Protection Commission, and the California Coastal Commission, all of which can make decisions overriding those by entities established more locally.

A major question in approaching the establishment of an RMA would be how to deal effectively with forces that either support or oppose its possible formation. Given the regional planning mandates represented by SB 375 and sustainable growth planning incentives, interests likely to support its formation would be those presently promoting heightened rail transit extensions, smart growth, and redevelopment of older downtown areas. Opposition would be expected from those members of the three organizations that are reluctant to relinquish current agency prerogatives to a coordinating authority as well as from subregional and local agencies concerned with maximizing local control.

One of the strongest factors leading toward formation of the proposed Southern California RMA will be increasing climate change impacts. The region will no longer be able to sustain its historically wasteful water consumption practices. Instead, long-term water resource limitations will require permanent changes on a massive scale in water supply and consumption patterns and in water conservation practices, such as runoff capture, groundwater retention and cleanup, low-consumption water-using appliances, and xeriscaping. Another goal will be to develop new local water sources such as seawater desalination and groundwater recycling of tertiary treated wastewater within the region.

Similarly, the region cannot sustain its traditional pattern of large-scale growth into far-flung areas. Instead, it will need to contain growth closer to existing urban centers, which can be encouraged by development of a more robust rail transit system. Without changes to the status quo, needed adjustments to these water use and growth patterns will be politically difficult, if not impossible, to implement under the current governance framework.

Conclusion

To maintain the region's viability, strong leadership will be required to reevaluate transportation and land use planning priorities to reduce GHG emissions, and to reorganize water supply, distribution, and conservation practices to help the region adapt to long-term supply limitations. As with most other physical and environmental changes, difficult social, economic, and institutional adjustment also will be necessary in order to develop the political will to move in new directions. According to Cayan (2009, 19):

> In the foreseeable future, Southern California expects continued growth in population, demand for energy and water, many more vehicles and miles traveled, and shifts in land use and ecosystems. Even in the best of circumstances, climate change will compound many of the problems associated with these developments. The early signs of climate change have already been recorded and considerably more change is on the way. How much more will be determined, to a large extent, by our collective global decisions and policies with respect to fossil fuel use and environmental protection.

Additionally, attention will need to be paid to minimization of development in hazardous zones, such as 100-year floodplains and WUI areas, and to investment in coastal development and conservation measures that can help counter sea level rise. All of this, in turn, calls for the evolution of existing institutional and political arrangements represented by SCAG, the MWD, and SANDAG into a new regional authority with skillful and far-sighted leadership at both the local and regional levels.

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Figure 5.1 San Francisco

Source: Weiss and Overpeck, University of Arizona.

dark blue overlay areas = low-lying coastal areas of ≤ one meter elevation vulnerable to future sea-level rise

Chapter 5

San Francisco

Laurie A. Johnson and Laura Tam

Northern California and the San Francisco Bay Area are already feeling the effects of climate change. The region has endured gradual increases in temperature and mean sea level as well as changes in precipitation for more than a century. Critical parts of the Bay's shoreline have already subsided well below sea level and are protected by a patchwork of fragile, old levees. The effects of climate change, particularly rising temperatures and sea levels, will seriously threaten the region's economy, infrastructure, environment, and cherished quality of life.

The San Francisco Bay Area

More than 7.1 million people inhabit the 7,000 square mile region comprising 9 counties and 101 cities in Northern California known as the San Francisco Bay Area—or just the Bay Area to local residents (figure 5.1). The region's population is projected to grow to more than 8 million by 2020, and could reach 12 million by 2050 (ABAG 2009). It is the fifth most populous region in the United States and the socioeconomic and cultural center of the northern part of the state. It is world-renowned for its geographic and architectural beauty, economic and cultural diversity, and highly valued standard of living.

The population is concentrated in the Bay Area's three largest cities—San Francisco, Oakland, and San Jose—and a number of smaller cities in the flatlands surrounding the Bay. San Francisco, the region's cultural and financial center, has the second-highest population density, after New York City, of any major city in North America. In terms of population and land area, San Jose is the region's largest urban area as well as one of its fastest-growing cities. It also forms the center of the financial and high-tech Silicon Valley area. Oakland is a major manufacturing and distribution center, rail terminus and hub, and site of the fourth-largest container shipping port in the United States.

The region is home to more than 3 million buildings, with a total value of $1 trillion (Kircher et al. 2006). Like many growing regions, however, the Bay Area is undergoing rapid changes, and it faces serious challenges, including traffic congestion, long commutes and overburdened transit systems, lack of sufficient housing and skyrocketing housing costs, loss of open space, declining neighborhoods, air and water pollution, and economic inequality.

San Francisco Bay, which covers close to 500 square miles, lies at the heart of the region. Freshwater drains more than 40 percent of the state's land mass via the Sacramento and San Joaquin Rivers and flows into the Bay in an area collectively known as the delta region (BCDC 2010a). The estuary formed at this confluence of rivers and sea is the largest on the U.S. Pacific Coast. Along with its shoreline marshes and wetlands, it provides food and shelter for a vast array of fish and wildlife, including harbor seals, geese, and thousands of other species of fish, plants, mammals, reptiles, and birds. An estimated 50 percent of the millions of birds that use the Pacific migratory flyway between the Arctic and South America rest and feed on the Bay each year (BCDC 2010a). Salt evaporation ponds at the south end of the Bay historically have been a major source of U.S. salt production.

The single narrow opening that joins the Bay to the Pacific Ocean through the Golden Gate also makes San Francisco Bay one of the world's great natural harbors. It is the fifth-largest U.S. port handling crude oil and the fourth-largest container port overall. In addition to the ports, the region's three major airports, oil refineries, and a variety of industries flank the Bay. A massive network of roads, highways, railroads, bridges, tunnels, and infrastructure crisscross the Bay and link together the region's urban, suburban, and industrial centers.

Just to the west, the Sacramento–San Joaquin River delta region contains unique habitat, highly fertile agricultural land, and critical infrastructure including pipelines, state highways, and power and communication lines. The delta is also the hub of the entire state's water supply. Diversions from this resource area provide water for about 25 million Californians, most of whom live in central and southern counties, and about 3 million acres of the state's farmland (CDWR 2009). Much of the delta's 700,000 acres of land is below sea level by as much as 25 feet and is protected by a fragile system of earthen levees stretching 1,330 miles, most of which holds back water every day of the year, not just during floods (CDWR 2009). Much of the levee system was built in the late 1800s and early 1900s, before modern seismic design and geotechnical engineering were put into practice. Since 1900, levees have failed and flooded delta islands 158 times. Over the years, many state and federal agencies and stakeholders have voiced concern about the condition of the delta and Suisun Marsh levees and the potentially catastrophic consequences should they fail.

Bay Area Climate Trends

The region's temperate, Mediterranean climate of mild, wet winters and dry summers greatly contributes to its appeal. It is controlled in large part by the cool temperatures of the Pacific Ocean and the Bay. But the topographic variation of surrounding hills and mountain peaks as high as 3,850 feet create an array of microclimates. Temperature variations in western areas near the Pacific Ocean generally are smaller throughout the year. Summers can be cool and foggy and winters mild and rainy. The eastern and inland areas have generally warmer summers and colder winter nights. The temperature variation can be quite pronounced, especially during the summer, when on a given day, inland areas can be more than 40°F warmer than foggy coastal towns.

Average annual rainfall also varies considerably across the region. Annually, inland and southern areas around San Jose can receive fewer than 15 inches, while areas to the north exceed 30 inches. San Francisco has an average of 67 rainy days a year, amounting to 20.4 inches. Except in the region's highest elevations, which may have an occasional dusting each year, snowfall in the Bay Area is rare.

The region's mild climate and the Bay itself combine to make this one of North America's greatest nexuses of biodiversity, and places the area among the top-25 global biodiversity hotspots as designated by Conservation International (Stein, Kutner, and Adams 2000). Just by itself the Golden Gate National Recreation Area—a national park spanning 60 miles of coastline and 75,500 acres of land in three Bay Area counties—is host to more than one-half of North America's bird species and nearly one-third of California's plant species.

Climate and Geologic Hazards

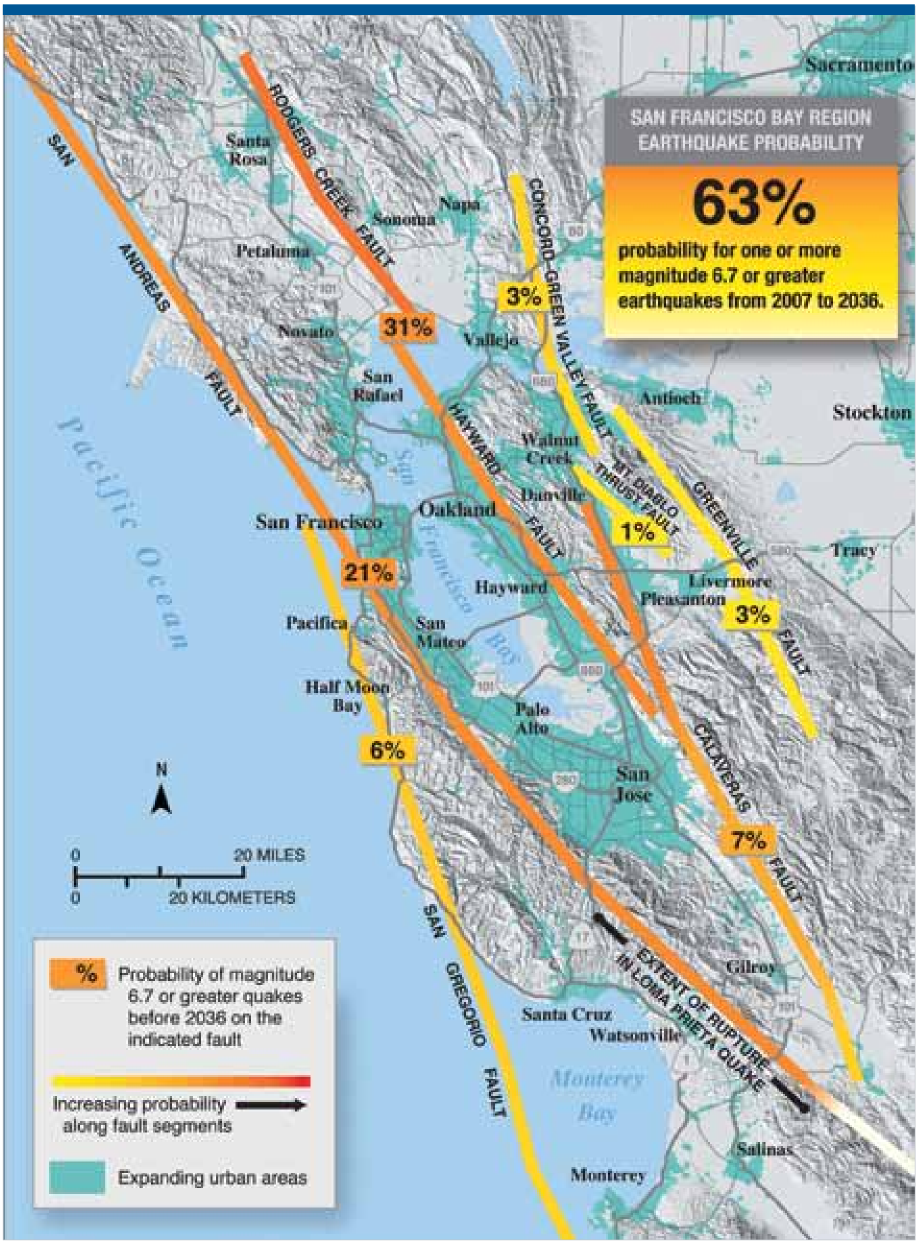
While the climate might seem quite benign, residents know all too well the extreme forces that can be unleashed with little or no warning. Californians often joke nervously about the four seasons in the Golden State: earthquake, landslide, flood, and wildfire.

The region's majestic setting is the result of strong tectonic forces, as the Bay Area sits astride the boundary between the North American and Pacific plates. In 1906, a magnitude-8 earthquake ruptured along the San Andreas fault—the major fault that defines this plate boundary—and the seismic shaking and resulting fire famously destroyed much of San Francisco. A portion of the same fault ruptured again in 1989 causing 57 deaths, destroying bridges and buildings across the region, and resulting in more than $6 billion (1989 US dollars) in reconstruction costs (Stoffer 2005).

More than 3 million of Northern California's residents live and work within 25 miles of the San Andreas fault, and it is just one of several major fault systems capable of generating powerful earthquakes (figure 5.2). The U.S. Geological Survey (USGS) and other scientific organizations have warned that there is a 63 percent probability that at least one earthquake of magnitude-6.7 or greater will strike the San Francisco Bay region before 2036 (USGS 2008). The Hayward fault, which is now overdue to rupture, is of particular concern because it runs through the densely urbanized East Bay corridor, where several key pieces of the region's major infrastructure either cross or lie in close proximity.

While climate conditions are not directly related to earthquake risk, many of the geologically most vulnerable areas of the Bay region are also among the most susceptible to climate impacts. Shorelines and riverside areas are subject

Figure 5.2 Major Faults and Probabilities of Rupture in the San Francisco Bay Area
Source: USGS (2008).



to intense shaking that can cause a phenomenon known as liquefaction, which transforms soil into a fluid mass. These areas are also vulnerable to sea level rise and flooding. The steep, hillside areas are susceptible to earthquake-triggered slope failures as well as landslides, flooding, and wildfires, all of which are triggered by climatic events. Strong winter storms can cause severe flooding as well as mudslides in the Santa Cruz Mountains and the more mountainous areas of the North Bay. These areas receive more than 55 inches of rain annually, and wet soil conditions struck by an intense winter rainstorm can lead to life-threatening mudslides. This occurred in 1982, when counties across the Bay Area experienced more than $66 million (1982 US dollars) in property loss (USGS 2010).

Table 5.1 Anticipated Statewide Climate Changes in California

Source: CNRA (2008).

	2050	2100
Temperature	2–5°F increase	3.6–9°F increase
Precipitation	12–35% decrease	Not available
Sea Level Rise	12–18 inches	21–55 inches

In spring and autumn, the strong offshore winds that develop periodically can cause dangerous wildfires, especially when hillside vegetation is dry. In 1991, for example, a catastrophic firestorm destroyed 1,520 acres of the East Bay hills in the cities of Oakland and Berkeley, causing 25 deaths and destroying 3,790 housing units valued at a total of $1.5 billion (1992 US dollars; Parker 1992).

Climate Change Impacts

In an effort to assess the state's vulnerability to climate change, a 2009 report on the California climate adaptation strategy (CAS) summarized the best-known science on the subject (CNRA 2009). It attempted to quantify future greenhouse gas (GHG) concentrations and project future potential changes in average temperatures, precipitation patterns, sea level rise, and extreme events. Using two emissions scenarios from a 2007 assessment conducted by the Intergovernmental Panel on Climate Change (IPCC), a set of six global climate models (GCMs) were run to determine anticipated climate changes for the entire state (table 5.1).

The CAS also cautioned that if no action is taken to reduce or minimize the expected impacts, the costs are apt to be severe. A 2008 report by researchers at the University of California, Berkeley, proposed that damages related to climate change could result in "tens of billions of dollars per year in direct costs … [and] expose trillions of dollars of assets to collateral risk" if California does not take action (Kahrl and Roland-Holst 2008, 4). More specifically, they estimate that climate change damage across the state could cost between $7.3 and $46.6 billion per year. Of the state's estimated $4 trillion in real estate assets, $2.5 trillion is at risk from extreme weather events, sea level rise, and wildfires, with a projected annual price tag of $300 million to $3.9 billion during the twenty-first century, depending on climate scenarios (table 5.2).

In addition, costs of disaster insurance, healthy food, water, and heating and cooling are all expected to rise. Access to support systems will become more limited for low-income communities. Overall, low-income communities will spend a larger percentage of their income to prepare and respond to climate change than will middle- and high-income communities (Morello-Frosch et al. 2009).

Table 5.2 Estimates of Economic Damage and Asset Risk for California, 2006
Source: Kahrl and Roland-Holst (2008, 4).

	Damage Cost/Year ($ billions)		Assets at Risk ($ billions)
	Low	High	
Water	N/A	0.6	5
Energy	2.7	6.3	21
Tourism and recreation	0.2	7.5	98
Real estate (water exposed)	0.2	1.4	900
Real estate (fire exposed)	0.1	2.5	1,600
Agriculture, forestry, and fisheries	0.3	4.3	113
Transportation	N/A	N/A	500
Public health	3.8	24.0	N/A
Total	7.3	46.6	3,237

Extreme Heat, Air Quality, and Health Effects

Past and future GHG emission levels are expected to cause the state of California to experience significant temperature increases during the next 30 to 40 years, especially in the summer months (CNRA 2009). Heat waves are expected to increase in frequency, and individual ones may also show a tendency toward becoming longer and extending over a larger area, thus encompassing multiple California population centers concurrently (Moser et al. 2009). Inland areas are likely to experience more pronounced warming than coastal regions. In the San Francisco Bay Area, the eastern and southern portions of the region are likely to see more pronounced warming than the coastal, northern, and central regions.

While the Bay Area may not experience the severity or frequency of extreme heat events—those in which three or more consecutive days surpass 100°F—that other parts of southern and central California are apt to face, increased temperatures could place additional stresses on health systems as well as local and statewide energy grids. Studies by the California Department of Public Health (DPH) show that there will be an increase in the average number of "extreme heat" days that exceed the region's 90th percentile average temperature (English 2010). From a twentieth-century baseline of about 12 extreme heat days per year, the number may increase to 32—or as many as 45—annually by mid-century; by the end of the century, it may be as high as from 70 to 94 days per year, representing as much as an eightfold increase overall. While the region's temperatures generally are mild, and these extremes may still seem to be "mild" when compared to other regions of the state, the DPH warns that Bay Area residents may be especially at risk, because they may have greater difficulty in adapting (English 2010).

Heat-related illnesses and deaths will increase, and these burdens will fall disproportionately on communities of color, the poor, the elderly, and infants (Morello-Frosch et al. 2009).

Increased annual temperatures are also anticipated to lead to shifts in the range, distribution, abundance, and natural community composition of both plant and animal species (Loarie et al. 2008). A loss of species abundance and diversity in some areas and increases in others is likely to result. Competition from nonnative and exotic species is expected to increase, as are diseases and pests, each of which will have a negative impact on the region's native flora and fauna. Many species are expected to shift to the north and to higher elevations as they seek refuge from hotter, drier conditions (Parmesan and Yohe 2003).

Because the dry seasons start earlier and end later, wildland forest fires have become more frequent and intense in recent years. Chronic smoke exposure from wildfire activity has already been observed in California's northernmost counties. Droughts are expected to increase in frequency, which suggests that wildfires will increase in both frequency and duration as well (CNRA 2009). The number of people and the value of the property at risk will also grow.

Precipitation, Water Quality, and Stormwater Management

The Bay Area is likely to experience abnormal types of water in unusual quantities, in odd places, and at atypical times. Most Bay Area communities today obtain their water from snowmelt in the Sierra Nevada Mountains in the eastern half of the state. Toward the end of the century, however, as little as 20 percent of the Sierra snowpack may exist when hotter, drier conditions caused by climate change are the norm. More precipitation will fall as rain rather than snow, which will have important implications for statewide water management (CNRA 2009). If rainfall and the runoff of meltwater begin earlier in the year, the state will face the significant challenges of storing sufficient water for the dry season while it manages floodwaters during the wet season. California's water supply, already stressed under current demands and expected population growth, will shrink under even the most conservative climate change scenario (CNRA 2009).

Independent of precipitation changes, higher air temperatures will increase evapo-transpiration and decrease soil moisture, leading to less runoff into reservoirs. Decreasing rainfall may also diminish local water supplies, even while higher temperatures are increasing water demand across all sectors. Longer, more intense droughts are predicted by 2100, leading to increased frequency and magnitude of water shortages, and potentially exacerbating conflicts between ecological protection and human consumption needs (SPUR 2011).

Reduced precipitation and increased evaporation will threaten the groundwater basins used for water supplies with lowered recharge (SPUR 2011). The basins are also at risk of increasing extraction to meet growing supply needs. For coastal freshwater aquifers, this may increase susceptibility to the saltwater intrusion that may result from sea level rise. Saltwater intrusion into coastal aquifers would make some of the freshwater unusable without desalination. When increased snowmelt combines with saltwater intrusion into the Sacramento–San Joaquin River Delta, the risk for flood-caused levee failures will also intensify, and such failures could potentially both destroy low-lying areas and contaminate freshwater supplies stored and conveyed in the delta (CDWR 2009).

Locally and regionally, both water excesses or floods that cannot be stored easily will occur. Given the regional drainage function of San Francisco Bay, storm floods can last longer in the Bay Area than in higher-elevation regions. Even today, the combination of high tides, storm surges, and river flooding can raise water levels in the delta by 4.25 feet for as long as a day (SPUR 2009). Low-lying areas protected by already fragile levees will be at even greater risk. Heavier downpours and increased runoff will also exacerbate overflows in San Francisco's combined stormwater and sewer systems as well as combined sewer systems elsewhere in the region.

Sea Level Rise

Sea level rise has been underway since the last ice age. The oldest tidal gauge still in operation in the United States, installed near San Francisco's Golden Gate in 1854, has measured a rise of about 8 inches over the last 100 years (SPUR 2009). Since the late 1990s, the rate of global sea level rise has increased by about 50 percent, and now it averages approximately 0.12 inches per year (SPUR 2009). In our view, sea level rise is probably the biggest climate change–related threat to the Bay Area (figure 5.3).

Climate Change Mitigation

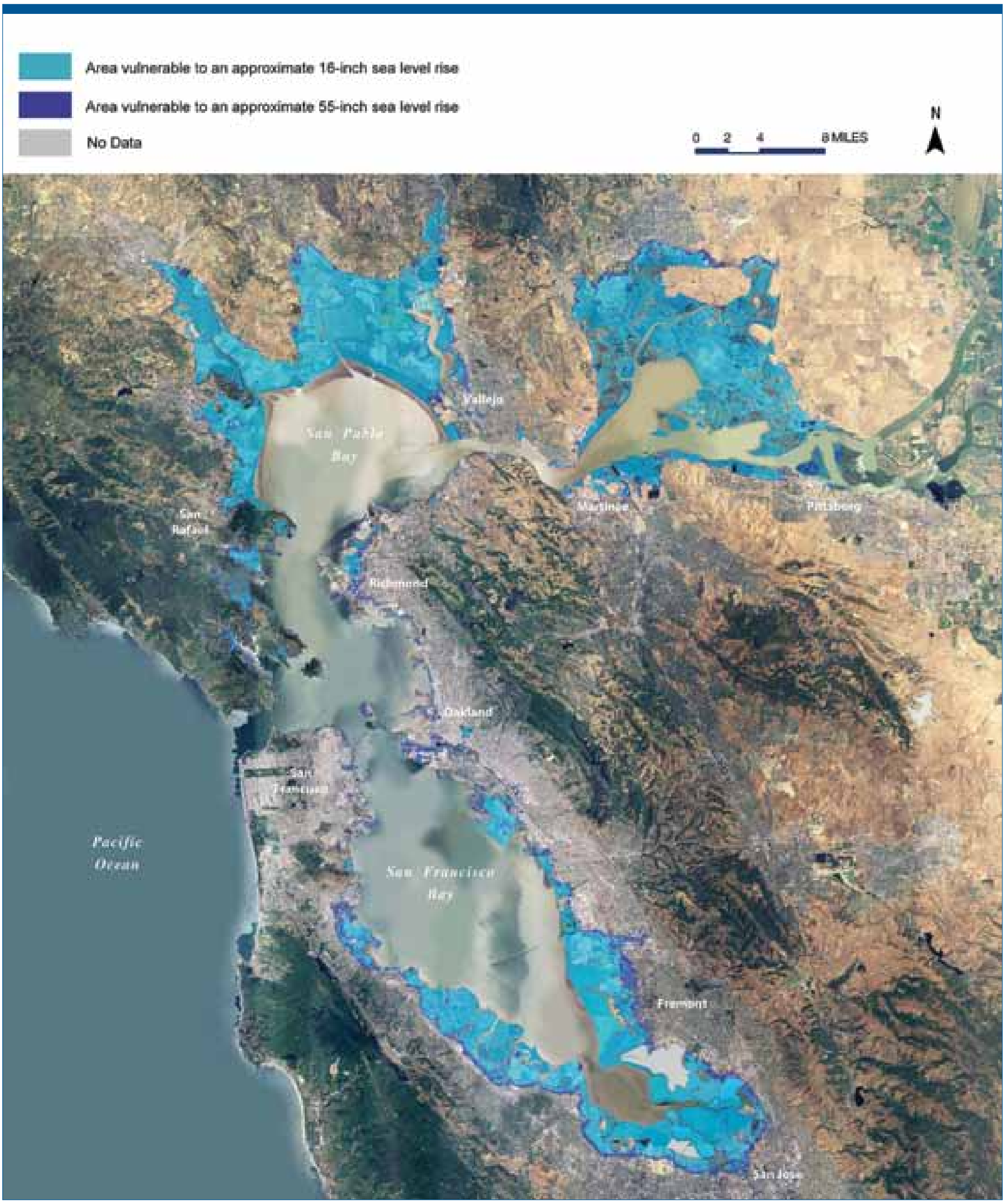
Statewide Responses

The State of California has been a nationwide leader in both mitigation of GHG emissions and development of adaptation strategies to combat the effects of climate change. Its efforts began more than a decade ago, when the initial focus targeted inventorying GHG emissions levels. It has since evolved, and more recently an emphasis has been placed on understanding anticipated climate change effects and developing adaptation strategies. Box 5.1 presents a synopsis of some key legislative milestones.

Local Responses

Many local governments also have created their own climate change action plans. In a popular model developed by the International Council for Local Environmental Initiatives (ICLEI) and widely adopted all over the world, cities use a standard methodology to inventory their GHG emissions. Many

Figure 5.3 San Francisco Bay Area Shoreline Vulnerable to Sea Level Rise
Source: BCDC (2008).



climate change action plans also establish an emissions reduction target by predetermined dates. Fewer of these contain implementation plans, identify funding for their efforts, or contain action plans for preparing and responding to the effects of climate change. Along with city and county governments, many local agencies have responsibilities for climate change risk manage-

Box 5.1 Government-Mandated Milestones in California's Climate Change Adaptation Strategy

2002: *Senate Bill 1078* established a Renewable Portfolio Standard that requires electricity providers to increase purchases of renewable energy resources by 1 percent per year until they have attained a renewable portfolio equal to 20 percent of resources used (Marin County 2006).

2006:

- Launch of the *California Solar Initiative Program,* a comprehensive $2.8 billion program intended to provide incentives for residential and commercial solar development over 11 years (Marin County 2006).
- *Assembly Bill 32—Global Warming Solutions Act*—mandates a first-in-the-nation statewide limit to reduce GHG emissions to 1990 levels by the year 2020, or 25 percent below forecast levels. By 2008, the state also must have established an implementation plan and a mandatory reporting system to track and monitor emission levels, and it also must have developed various compliance options and enforcement mechanisms (Marin County 2006).

2008:

- *Senate Bill 375* establishes a new framework for reducing GHG emissions; it requires regions to develop growth strategies that align transportation funding with housing needs (Greenbelt Alliance 2009).
- *Executive Order S-13-08* calls upon state agencies to develop California's first strategy to identify and prepare for expected climate impacts. The 2009 CAS report summarizes the best-known science on climate change impacts for the state and becomes the first step in an ongoing, evolving process to fulfill this executive order (CNRA 2009).

ment. Among them are agencies that deal with water supply and wastewater, airports and port management, transit and transportation, parks, planning, and redevelopment.

The climate planning efforts of two early leaders in the Bay Area are highlighted below. Both are focused on reducing GHG emissions in their respective local government's area, not the entire region or beyond.

Marin County Greenhouse Gas Reduction Plan. In April 2002, the Marin County Board of Supervisors adopted a resolution committing the county to analyze emission levels, set a target, develop a local action plan, and then implement it. The resultant Marin County Greenhouse Gas Reduction Plan, adopted in 2006, contained policies that both reduce emissions and adapt to climate change (table 5.3).

City and County of San Francisco. Relatively early on, San Francisco—both as city and county—adopted GHG emission reduction targets and developed a strategy to achieve them. The city's climate action plan, adopted in 2004, contained a baseline inventory of emissions in the city in 1990, and its numeric target for 2012 was 20 percent emissions reduction below 1990 levels (SPUR 2011). Besides containing an inventory and overall goals, the plan recom-

Table 5.3 Policies from Marin County's Greenhouse Gas Reduction Plan
Source: Marin County Community Development Agency (2006).

Policies for Reducing GHG Emissions	Adaptive Climate Change Policies
• Increase renewable energy • Conserve electricity • Change commuting and driving patterns • Divert solid waste • Increase bio-capacity of open space and agriculture • Increase local food availability and sustainable agriculture	• Plan for sea level rise • Seek levee assistance • Consider future threat of sea level rise • Establish a climate change planning process • Revise and implement floodplain ordinance • Limit development to accommodate migration of coastal wetlands inland (in response to sea level rise) • Promote restoration of wetlands and riparian areas to provide capacity for high water and flood flows

mended actions and named specific targets for each category. In transportation, for example, certain actions included increasing transit use, bicycling, and walking; through these actions the use of clean-air vehicles was encouraged, while driving in general was discouraged. Energy-based actions included increasing efficiency by means of offering incentives and direct installation, expanding education and outreach, developing renewable energy projects, and increasing green power purchasing.

The city has also developed aggressive green building rules that govern new construction, and it offered residents and businesses financial incentives for purchasing solar arrays and making energy efficiency improvements. Recycling and composting are mandatory, boosting the city's waste diversion rate, which is already the highest in the nation.

San Francisco has also improved the municipal-vehicle fleet and requires city agencies to write their own individual climate action plans. Its citywide climate action plan, however, had no action items to address climate change preparation and adaptation.

Impacts of Sea Level Rise on the San Francisco Bay and Coastline

The State of California's Scenarios Project estimated in 2009 that up to 18 inches of sea level rise will occur by 2050, 55 inches by 2100, and much more after that (CNRA 2009, 15). Localized effects and rates of sea level rise can vary widely, however. Areas that have been experiencing land subsidence due to groundwater extraction or loss of marshes could experience the impacts of sea level rise sooner and perhaps with greater intensity. For example, some communities in the South Bay mined groundwater through the 1960s and their lands have subsided by as much as 13 feet (SPUR 2011). Also, heavily channelized and diked parts of the delta are now as much as 25 feet below sea level (CDWR 2009). In the near term, most of the expected damage from sea level rise on developed areas will result from surges occurring during storms that coincide with high tides (SPUR 2009).

A recent study conducted by the USGS and Deltares, a Dutch research institute, modeled hydrodynamic changes that could result from sea level rises ranging from 1.6 to 16.4 feet in the South Bay (SPUR 2009). It found that sea level rise there will be linear with the ocean; that is, the bay will neither amplify nor change tidal characteristics. The study also found that flow speeds will be higher, particularly south of the Dumbarton Bridge, which could increase erosion and affect shipping for the Bay Area's ports. Finally, the findings suggest that, in general, wave heights will increase as a result of deeper water and higher winds, exacerbate erosion, and pose a potential hazard for recreational areas.

Along the Pacific coast, storms increase winds, especially those directed onshore, which will cause bigger, more erosive waves and accelerate coastal erosion, particularly from vulnerable dunes and cliffs. A 4.6 foot rise in sea levels could cause loss of more than 10 square miles of land along the region's four coastal counties (Heberger et al. 2009). This effect also places thousands of individuals as well as significant transportation-related infrastructure and property along the region's coastline at risk.

According to a 2009 study by the Pacific Institute, approximately $30.8 billion (in 2000 US dollars) worth of buildings and contents on the Bay Area's coastal and bay shores are currently vulnerable to a 100-year flood, which is defined as a 1 percent annual probability of being flooded (Heberger et al. 2009). With a 55-inch rise in sea levels, that figure increases to $64.3 billion (2000 US dollars) if no adaptation actions are taken. Most of that property is residential and concentrated on San Francisco Bay. Using population growth projections from 2008, a 55-inch rise in sea level will put 276,500 of the Bay Area's residents at risk of a 100-year flood event (Heberger et al. 2009). These impacts will be experienced disproportionately by communities of color as well as low-income households, which tend to be in low-lying areas. A disproportionate percentage of Bay Area households vulnerable to flooding are linguistically isolated—that is, no one older than 14 speaks English (Heberger et al. 2009)—which presents special challenges for emergency response and public health and education campaigns.

Increases in sea level rise directly threaten the region's infrastructure, including its major highways and bridges, two of its three principal airports, its ports, power plants, emergency facilities, and wastewater treatment facilities. The 22 wastewater treatment plants on the Bay Area's shoreline are vulnerable to a rise of 55 inches in sea level (Heberger et. al. 2009). Many of them lack the capacity to handle current storm flows, and that could lead to more frequent sewage spills. During high tides, saltwater intrusion into combined wastewater-sewer systems is likely to increase, leading to saline water reaching the treatment plants, which has the potential to compromise treatment processes. The number of regulated hazardous waste facilities or sites vulnerable to a 100-

year flood event will more than double—to 235 sites—with a rise of 55 inches (Heberger at al. 2009).

Vast areas of wetlands and other natural ecosystems along the coast, bay, rivers, and streams are also vulnerable to sea level rise. If available sediment in the bay is insufficient, tidal wetlands will not be able to maintain vertical elevation as sea level rises (SPUR 2011). Lacking room for wetlands to migrate landward as sea level rises, existing wetlands will become submerged, and losses could be as great as 50 to 70 percent in the South Bay, depending on other contributing anthropogenic factors, such as subsidence (Galbraith et al. 2002).

Finally, rising sea level, in combination with changes in timing and quantities of fresh water flows from the delta, is likely to increase salinity levels further up into the delta (CDWR 2009). A reduction in freshwater inputs to the bay resulting from longer, drier summer periods is projected to shift the salinity gradient eastward during spring and summer (Knowles and Cayan 2002). This shift may be exacerbated by potential changes in the management of delta water resources for human uses, including water supply and agriculture. The salinity increase may reduce plant diversity and threaten several locally uncommon and rare plants in the delta (BCDC 2009).

Policy Responses to Adaptation and Sea Level Rise

Statewide Responses

Late in 2009, the California Natural Resources Agency released its Climate Adaptation Strategy (CAS), as required by the governor's executive order. To develop this strategy, CNRA established seven sector-specific working groups led by twelve state agencies, boards and commissions, and numerous stakeholders. The groups focused on public health, ocean and coastal resources, water supply and flood protection, agriculture, forestry, biodiversity and habitat, and transportation and energy infrastructure (CNRA 2009).

The report summarizes the best-known science on climate change impacts in the state and recommends a set of 12 strategies organized into near-term and long-term and specifying participating agencies already committed to completing the near-term strategies (Malchow 2009). Long-term strategies may change as further research becomes available.

The strategy contains three broad directions regarding sea level rise that represent a clear approach in the state's guidance and policies about this threat. First, the strategy directs state agencies generally to avoid permitting or siting new development in areas that cannot be adequately protected and are at high risk of flooding, wildfire, or erosion due to climate change. For sea level rise, this is a form of managed retreat: recommending that things not be built where they will require expensive flood protection during their design life. However, the strategy acknowledges that certain shoreline areas that already have significant economic-development, cultural, or social value will need protection in the future, and infill development in these locations could be accommodated. How state agencies, particularly those with shoreline responsibilities, such as the Coastal Commission and the Bay Conservation and Development Commission (BCDC), will interpret this guidance is not yet clear, although a case-by-case basis seems likely, especially in Bay Area cities. The strategy suggests that local governments and regional agencies follow these guidelines within their jurisdictions as well.

The second new direction pertains to future interpretation of the California Environmental Quality Act (CEQA), a detailed environmental impact review process that affects nearly every large planning and development project in the state. Adopted in 1970, CEQA requires all public agencies statewide to identify environmental impacts associated with a proposed project and to provide feasible measures to mitigate any significant adverse impacts it may entail. CEQA applies to all large-scale discretionary projects at all levels of government, including approval of general or specific plans and public or private projects for development and redevelopment by state, regional, and local agencies. The CAS recommends that, in their CEQA reviews, all state agencies consider the potential ramifications of locating new projects, including those involved with infrastructure, in areas susceptible to hazards resulting from climate change. It also directs CNRA to revise the section of CEQA that directs how agencies should evaluate the impacts of locating development in areas susceptible to hazardous conditions.

The third new direction aims at local governments, which are responsible for almost all of the planning activities in the state. The CAS urges local governments to update general plans—as well as local coastal plans, which are certified by the California Coastal Commission (CCC)—to assess climate change impacts and identify vulnerable areas. These plans, then, should use the best available information, some of which could be provided by the state, to identify prudent risk reduction strategies for those areas. Although cities update their general plans every five years, there is no funding either for this process or attached to the CAS and no requirement for local governments to update certified local coastal plans. Without better guidance, examples, and funding, this strategy is likely to be implemented very slowly. To provide technical assistance, the state is developing a Web-based mapping tool called Cal-Adapt to help local governments identify their vulnerabilities based on the latest climate research.

Regional Responses: The Bay and Delta

The BCDC, a state agency whose establishment in 1969 preceded most federal and state environmental laws, is the lead government agency advancing sea level rise planning in the San Francisco Bay region. BCDC's climate change program focuses on advancing research and developing strategies to reduce the region's vulnerability to the impacts of climate change. BCDC regulates bay fills, protects public access, and prevents degradation of the San Francisco Bay and the Suisun Marsh. It also convenes stakeholders and represents state and regional interests in advancing policies to protect the bay. Along with the CCC, it is empowered to implement the federal Coastal Zone Management Act in California, which gives both agencies regulatory control over federal activities in the coastal zone. The CCC also certifies and regularly reviews coastal plans filed by local governments.

In 2009, BCDC issued a report on the bay's vulnerability to sea level rise that featured the latest research on the subject, recommendations of planning strategies for local governments, and detailed maps (BCDC 2009). BCDC is planning to update the San Francisco Bay Plan, its guidance document, to add findings and policies on sea level rise. However, the ability of BCDC to regulate use of land threatened by sea level rise or to permit development that accommodates it is severely restricted. The agency's jurisdiction is limited to designating priority uses within 100 feet of the high-tide mark, and the only condition that it is mandated to protect is public access to the shoreline. Yet the idea of providing more authority to BCDC to regulate land use by taking those powers away from local jurisdictions has not yet achieved public consensus.

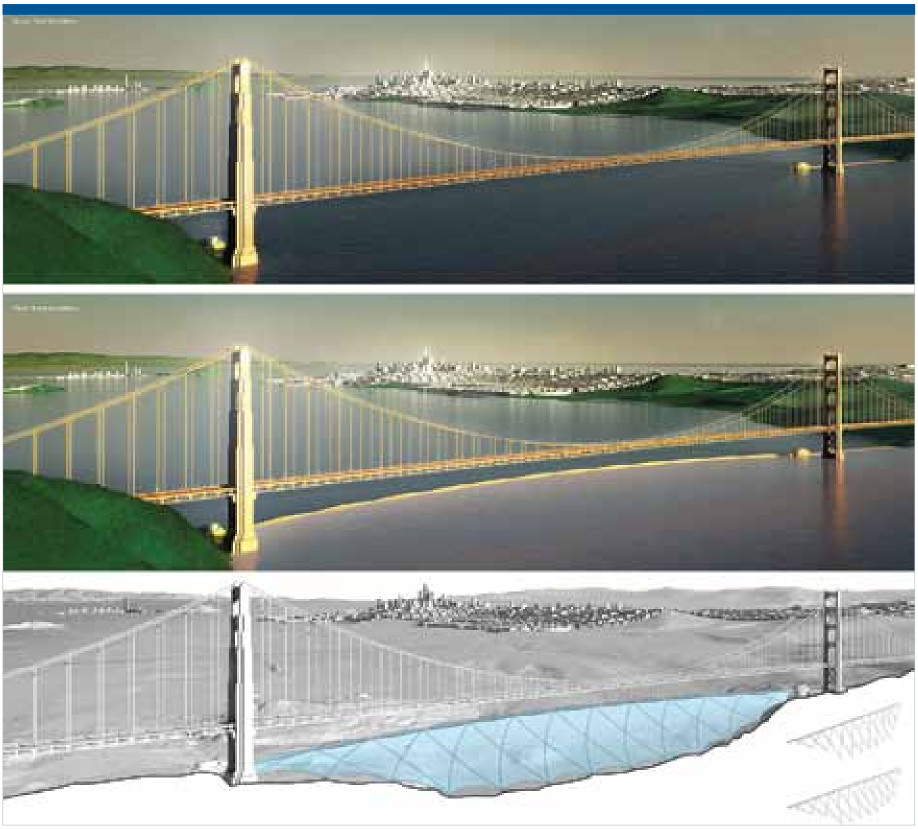
On its Web site BCDC has created a virtual climate change adaptation resource that offers data and information related to planning for impacts in the San Francisco Bay Area. In 2009, it also sponsored Rising Tides, an open international design competition seeking ideas that respond to sea level rise in San Francisco Bay. Six winners were selected from 140 entries (BCDC 2010a) including two plans for barrier construction outside the narrow Golden Gate, a plan to retreat from the Bay using topography as a guide, and construction of a series of laser beams around the Bay to show the potential location of levee barriers as a form of public education (see figure 5.4).

In the San Francisco Bay Delta, adjacent to the bay's northeastern boundary, sea level rise and storm surge pose a high probability of devastating whole islands. The Delta Risk Management Strategy (DRMS, pronounced *dreams*)—mandated by a governor's executive order—is developing a menu of risk reduction measures, packaging the measures into different combinations or scenarios, and using a model to evaluate their effectiveness, benefits, and costs.

The DRMS risk analysis combines the various types of hazards (e.g., earthquakes, flooding, high wind waves and erosion, undetected problems, and the effects of climate change and continuing subsidence), the frequency of each at different magnitudes, and the consequences of failures under each condition for 50, 100, and 200 years into the future. For example, sea level rise is expected to put more pressure on delta levees in the future, climate change is expected to increase high flood flows into the delta during winter, and population growth within the delta will increase the consequences of levee failures and flooding.

Figure 5.4 Proposed Barrier to Control Sea Level Rise Inside the Golden Gate, BCDC Rising Tides Competitor Winner

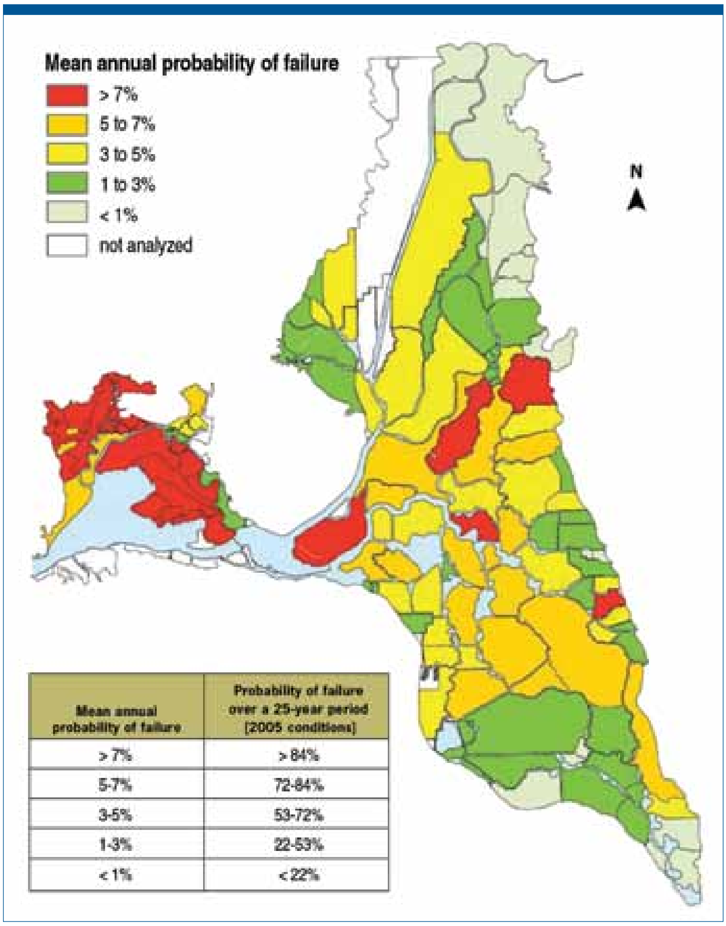
Source: SOM Skidmore, Owings & Merrill LLP; BCDC (2010b).



Phase 1 of the DRMS analysis, released in 2009, concluded that under business-as-usual practices, the delta region as it exists today is unsustainable. Seismic risk, high-water conditions, sea level rise, and land subsidence threaten levee integrity. An earthquake is the single greatest risk to levee integrity in the delta region because it could cause multiple levee failures allowing simultaneous flooding of as many as 20 islands. This would result in fatalities, extensive property damage, and the interruption of water supplies from the delta for periods from several months to years in length. If such an event occurs during a time of low to moderate freshwater inflow from rivers and streams into the delta, saline water from Suisun Bay would move upstream into the delta. Irrigation, distribution of local urban supplies, and state and federal water project exports all could be affected. Impacts on the delta's ecosystem would also occur, and the economic costs and repercussions would likely exceed $15 billion.

The analysis also concludes that the risk of flooding and levee failure in the delta region will increase only if current management practices are not changed. The combined risk of an individual island being flooded due to earthquake, high water, and dry weather events were also estimated. Considering the

Figure 5.5 **Combined Risks of Levee Failure in the Delta Region**
Source: CDWR (2009).



Mean annual probability of failure	Probability of failure over a 25-year period (2005 conditions)
> 7%	> 84%
5-7%	72-84%
3-5%	53-72%
1-3%	22-53%
< 1%	< 22%

probability of levee failures from all hazards under business-as-usual practices, the expected mean annual probability of island flooding is as high as 7 percent for some delta islands, and those in Suisun Marsh and the western and central delta are the most vulnerable (figure 5.5).

Currently, three multiperil risk reduction scenarios are being evaluated, and they take different approaches to adapting the delta to the effects of climate change (CDWR 2007). The first would improve levees and construct an armored infrastructure corridor across the central delta that would include rail lines, a major aqueduct, and a state highway. It would also change land use from farming to wetlands and carbon sequestration for all islands projected to have more than 3 feet of additional subsidence by 2100. The second scenario envisions all these changes plus a central pathway of levees providing a 300-year level of earthquake protection. The last scenario incorporates all of the changes included in the first scenario, but adds a peripheral canal that would divert freshwater flowing into the delta and into the state's water project distribution system to the Central Valley and Southern California. The results from DRMS will provide levee risk information for other initiatives and planning efforts that cover all or portions of the region, such as the Bay Delta Conservation Plan.

Local Responses

Local agencies and utilities already engage in climate change adaptation planning. For example, water supply agencies in California are required to file five-year urban water management plans that detail how they will ensure that supply meets projected demand. Recent state legislation requires even greater water conservation—a 20 percent reduction in water use by 2020. In part, this helps the state deal with the existing challenge of water scarcity, but it also builds resilience for water cycle changes, such as loss in snowpack, long-term drought, and other impacts that will be exacerbated by climate change. Other institutions relatively well positioned to adapt to climate change include local public health departments, which already monitor disease outbreaks and respond to projected health emergencies, and fire departments, which have been responding to larger and more frequent wildfires in California for some time.

Sea level rise, however, is a confounding problem for local governments, and none in the Bay Area has adopted a comprehensive approach or plan to handle projected increases of either the bay or the Pacific Ocean. Generally, local government planning efforts are underfunded, and sea level rise has yet to be given priority in local budgeting because it is perceived as a new threat that will not cause significant harm or require emergency response for years, if not decades. No public consensus exists concerning ways to plan for sea level rise or the most appropriate strategies for local governments to adopt in terms of managing risk, finances, and land use. Hope that federal, state, or even regional organizations will step up with resources and planning tools that local governments will need also causes delay in addressing these issues.

The problem of sea level rise is gaining recognition nonetheless, and two types of local endeavors are deepening public engagement in this area of planning. First, efforts of Bay Area nonprofit organizations, research universities, and think tanks that conduct research and publish findings on the subject are often disseminated through the local media. In just the past five years a great deal of work on climate change adaptation has been published. The Pacific Institute, a prominent research organization in Oakland, published a seminal study in 2009 on the effects of sea level rise on the California coast (Heberger et al. 2009). Funded by three state agencies, that study included detailed risk assessments, maps, cost estimates for shoreline protection (table 5.4), and recommendations. It suggests that, to protect against future sea level rise, approximately 642 miles of new or modified coastal-protection structures are needed on the Pacific Coast and San Francisco Bay, with a total cost for building or upgrading estimated at $5.27 billion. The Pacific Institute's study significantly informed the California Climate Adaptation Strategy.

In 2008 the Public Policy Institute of California (PPIC), a statewide think tank based in San Francisco, published *Preparing California for a Changing Climate,* a major report accompanied by six supporting papers that evaluate preparedness and adaptation strategies for various sectors of the state. PPIC's evaluation of coastal planning efforts for sea level rise revealed that few agencies or utilities with jurisdiction, property, or permitting authority within the expected inundation area were planning explicitly for that risk.

In 2011, the San Francisco Planning and Urban Research Association (SPUR), an urban planning think tank, published a white paper describing the

Table 5.4 Estimates of Capital Costs for Levees to Prevent Flooding from Sea Level Rise in Northern California Counties

Source: Heberger et al. (2009).

County	Raise Levee (miles)	New Levee (miles)	New Seawall (miles)	Total (miles, approx.)	Capital Cost ($M year 2000 US dollars)
Alameda	45	49	16	110	950
Contra Costa	26	29	8	63	520
Marin	43	77	8	130	930
Napa	3	62	—	64	490
San Francisco	—	10	21	31	680
San Mateo	35	29	9	73	580
Santa Clara	47	4	—	51	160
Solano	3	63	8	**73**	720
Sonoma	30	15	1	47	240
Total	**232**	**338**	**71**	**642**	**5,270**

Note: Estimates in miles and capital cost of defenses required to protect against flooding are based on a 55-inch rise in sea level.

expected impacts on the Bay Area of climate change and making recommendations for how cities, regional agencies, and utilities should prepare (SPUR 2011). It reviewed vulnerabilities and offered strategies in six key planning areas: public health and safety, water management, energy, transportation, ecosystems and biodiversity, and sea level rise. SPUR's analysis also weighed the theoretical advantages and disadvantages of the following seven physical planning strategies for management of sea level rise in the bay:

- *Barriers or tidal barrages* situated at the Golden Gate or in smaller, strategic parts of San Francisco bay to manage tidal flows;
- *Coastal armoring* with linear protection (e.g., levees and seawalls) to fix the shoreline in its current place;
- *Elevated development* in which the height of land or existing development is raised and protected with coastal armoring;
- *Floating development* anchored in place, or which may be floated occasionally during a flood, making it largely invulnerable to changing tides;
- *Floodable development* designed to withstand flooding or to retain stormwater;
- *Living shorelines* with wetlands that absorb floods, slow erosion, and provide habitat; and

- *Managed retreat* that safely removes settlement from encroaching shorelines, allowing the water to advance unimpeded, and bans new development in areas likely to be inundated.

Regional awareness is also growing around the issue of sea level rise through the public review process for two proposed shoreline development projects in the Bay Area. Treasure Island and the Redwood City Saltworks, both on San Francisco Bay, have incorporated sea level rise projections and adaptations into their proposed redevelopment plans and as of early 2011 were seeking approval.

Treasure Island is a former U.S. Navy base occupying a low-lying, man-made island in the middle of San Francisco Bay. The redevelopment plan proposed by Treasure Island Community Development LLC (TICD) is a model of smart growth, transit-oriented, and green development (figure 5.6). Sea level rise protection plans include raising and seismically retrofitting the 25 percent of the island that will constitute the new building pad, then setting it back 300 feet from the high tide mark and building levees at the water side of the setback (Seifel Consulting 2010). This plan is adaptable to uncertain future sea levels because the levees are designed to be raised when needed in the future, but the cost does not need to be absorbed by the project initially. TICD also proposes to use an infrastructure financing district, a tool unique to California that creates a designated assessment district to finance districtwide improvements to public amenities.

Redwood City Saltworks proposes to redevelop 2.2 square-miles of active salt farming ponds on the western shore of San Francisco Bay (figure 5.7). The project would restore 436 acres of wetlands on its bay side and build a levee topped with a recreational path adjacent to the 12,000 new housing units and commercial, office, and other facilities that will occupy the other 50 percent of the site (City of Redwood City 2011). The Saltworks plan helps the region address its housing shortage, protects housing with a levee in the case of future sea level rise, and provides one million square feet of protected commercial space. Although it is near downtown Redwood City, to be truly transit-oriented it will require new transit extensions. The proposed project is controversial because the salt ponds have been identified as an opportunity site for restoration of wetlands. Today, tidal marshes occupy only about 8 percent of their original extent in San Francisco Bay, due to filling, armoring, and reclamation activities. Currently, however, no identified financing is in place to buy or restore this site for wetlands or to protect any housing in Redwood City that may be vulnerable to future flooding.

Both projects are in areas that are vulnerable to earthquakes and floods, and both propose to protect themselves from anticipated future sea level rise. Tens of thousands of new homes will add much-needed housing in viable locations and, by increasing supply, help support affordability in the region. The

Figure 5.6 Proposed Treasure Island Development in San Francisco Bay
Source: Treasure Island Community Development, LLC.

proposed urban designs of both sites align with new urbanism principles: They are walkable, compact, transit-oriented, and mixed use. Although neither project is on an infill site, both propose to redevelop underutilized parcels near major transit nodes and employment centers. As they undergo the entitlement and environmental review processes in 2011, each one becomes a litmus test for how the Bay Area will plan for future sea level rise.

Climate Change Lessons, Issues, and Next Steps

In a recent poll, a commanding majority of Californians expressed concerns that climate change has already begun and that it poses a serious threat to the state's economy and quality of life. PPIC reported that "the key policy question is whether California's institutions have the information, tools, and resources to craft responses that encourage individuals and society as a whole to adjust and adapt to these changes" (Bedsworth and Hanak 2008, 3).

A statewide policy framework to address both climate change mitigation and adaptation has been developed, and mitigation strategies have already begun to be implemented. Studies have helped characterize the potential impacts of climate change for both the state and region. Even though most local governments lack sufficient resources to address adaptation planning broadly, many already are considering, case-by-case, projects proposed to manage sea level rise in various ways. Yet even with all these developments, five critical gaps still must be addressed in order to achieve definitive success.

Aerial view of the existing salt ponds that encompass the proposed Redwood City Saltworks Redevelopment Project in South San Francisco Bay
Photograph © Cargill Incorporated

First, the San Francisco Bay Area's key regulatory institutions need a toolkit of legal and regulatory powers that will help manage anticipated effects of climate change. For example, the authority to implement strategic decisions on adapting to sea level rise held by both the BCDC and the CCC—the two agencies that presently have jurisdiction in the shore zone—is severely limited. In the face of this new risk, state law may need to be amended to broaden the scope of authority for both commissions.

These agencies, along with local governments, which do most of the land use planning in California, also must reassess strategies for permitting and authorizing changes or expansions for the bay's and coast's major facilities, such as airports, ports, and wastewater treatment facilities. Today, for permitting purposes, BCDC and the CCC assume that new development will have a 50- to 90-year lifespan. Starting now, climate change should be factored into the design of all new shoreline structures, especially those that are part of critical infrastructure. These agencies must also help determine how to prioritize funding to protect the significant social and economic resources that are at risk.

To fill the second gap, a new entity may be needed to govern the Sacramento–San Joaquin River Delta, because here, two major climate adaptation issues now added to earthquake risk have come to a head: water supply and sea level rise. The delta's problems are well known, yet thus far millions of dollars and numerous planning processes have failed to achieve the twin goals of water provision and ecosystem restoration that long have been the state's priorities for the region.

To wrestle with the third potential deficiency, new land use or regulatory authority for state-level organizations should be paired with tools and financing for local governments so that they can mitigate flood hazards by amending zoning or designating special districts. Local governments also need a sustained source of funding along with potential technical assistance to complete vulnerability assessments, develop climate change strategies, and execute effective implementation programs. Although not required currently, cities and counties should consider updating their coastal plans, many of which were developed in the 1980s, before sea level rise became a recognized concern. Findings and policies on climate change hazards should also be considered as local governments update their general plans. Local planning processes need to involve vulnerable populations in the development of appropriate preparation and adaptation strategies.

Fourth, ecological migratory paths need to be delineated and protected to safeguard the health of the bay, which itself is an iconic environmental and economic resource. This habitat includes wetlands that have been destroyed in more than 90 percent of their original extent in San Francisco Bay and, in some places, whose restoration could help buffer developed areas from flooding. Bay management agencies should take a lead in identifying opportunity sites for restoration. Conservation organizations and local governments can also help identify migratory paths and conservation opportunity areas for other key plant and animal species that are threatened by climate change.

Finally, California has long supported research to identify specific climate changes and threats making today's knowledge about future climate effects much greater than it was even a few years ago. Financial and technical support is needed to improve the basic science and modeling concerning climate impacts, particularly with respect to downscaling global models to regional and local levels. For example, climate in the Bay Area is varied, which is especially noticeable in the summer when the marine fog makes the considerable temperature differentials between inland and coastal areas particularly evident. This will mean that, even with a coherent regional strategy for sea level rise in place, the region must plan for temperature and air quality differences throughout. A better understanding of the effects of climate change in each microenvironment—especially as global climate models continually improve—would help ensure predictability for planning.

That California leads all other U.S. states in planning for climate change is acknowledged widely, but now is the time to continue this progress by improving science and governance to keep the state's citizens safe in a future of warmer days and higher seas.

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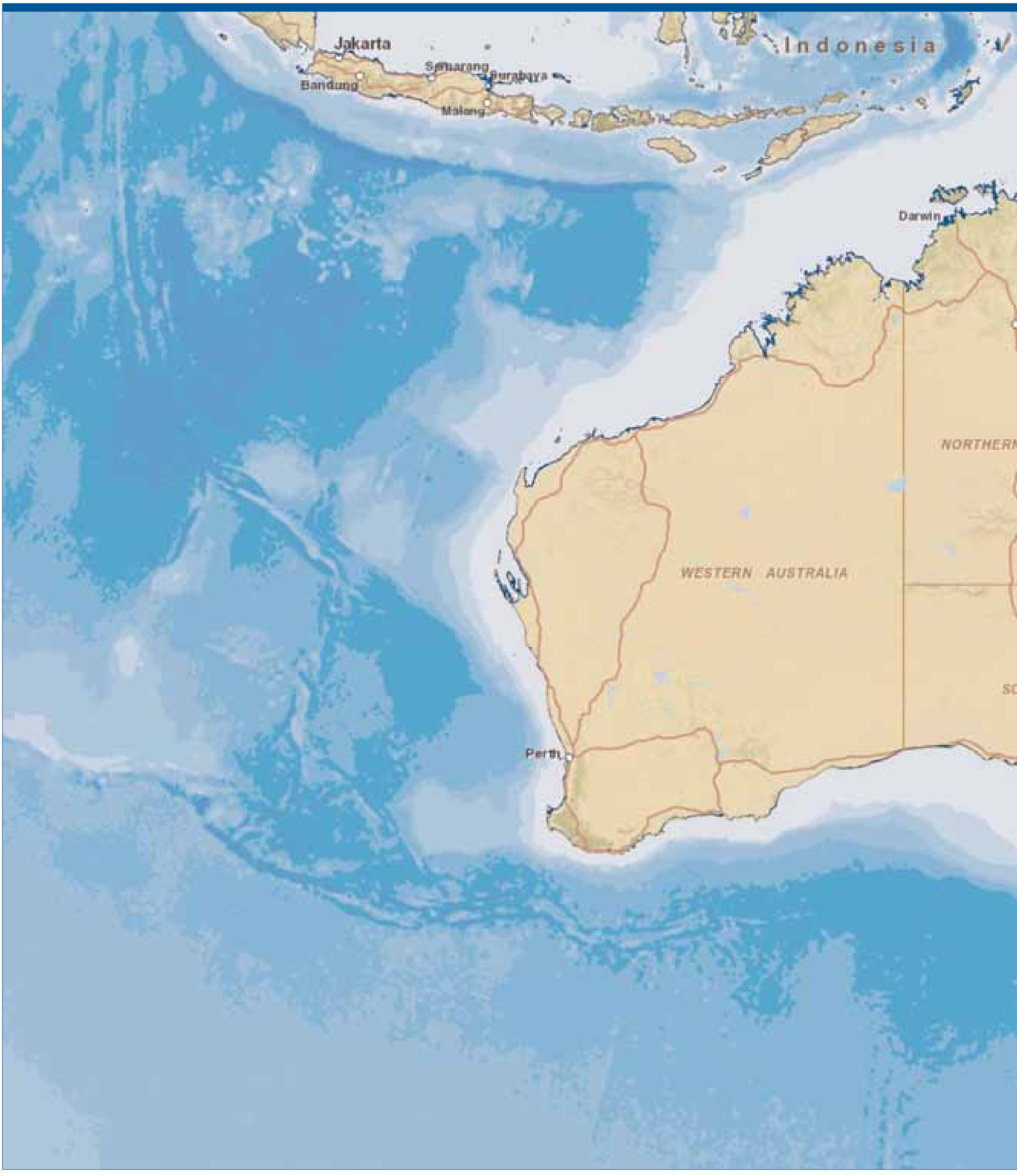
Australia

Source: Weiss and Overpeck, University of Arizona.



dark blue overlay areas = low-lying coastal areas of ≤ one meter elevation vulnerable to future sea-level rise


Papua
New
Guinea
Port
Moresby
Coral
Sea
Daly
Waters
TERRITORY
QUEENSLAND
Australia
Brisbane
UTH AUSTRALIA
NEW
SOUTH
WALES
Sydney
Adelaide
Canberra
VICTORIA
Melbourne
Hobart
Tasman Sea
New Zealand

Figure 6.1 Melbourne

Source: Weiss and Overpeck, University of Arizona.

dark blue overlay areas = low-lying coastal areas of ≤ one meter elevation vulnerable to future sea-level rise

Chapter 6

Melbourne

Peter M. J. Fisher

Melbourne, the state capital of Victoria in southeastern Australia, is a large seaboard city (figure 6.1). Prior to the rise of global warming concerns, decadal climate variation across the region has been viewed as a gradual, creeping process—not entirely human-friendly, but unlikely to make the state a difficult place to live. If considered at all, anthropogenic climate change was not regarded as likely to occur. By the mid-2000s, however, some people became concerned about a 12-year drought arising from a prolonged El Niño event and punctuated from time to time by a weak La Niña event that resulted in diminished dam levels, severe water restrictions, and dustbowl conditions. Then on 7 February 2009, later named Black Saturday, killer firestorms to the east and north of Melbourne incinerated 173 people and a million animals. The fires burned 450,000 hectares (ha), destroyed more than 3,500 buildings, injured 414 people, and displaced 7,562 others. Once temperatures and winds reached extreme proportions, the dryness already in effect was an invitation to cataclysmic fire.

Shaken by the failure of fire plans to prevent this tragedy, the Labor government then in power established the Victorian Bushfires Royal Commission (2009a) and declared "unconditional support for residents wishing to rebuild their homes and towns" (*Weekly Times* 2009, 1), regardless of whether those sites were safe—the very matter the commission was charged to investigate. The government seemed neither to recognize nor address the distinct possibility that climate change is altering the vegetation as a result of frequent devastating fires in settings where there has been a considerable influx of "tree change" residents. James Hansen and his colleagues predict that there will be even more extreme summer heat events, which indicates that very hot fires are also likely and will only hasten that vegetative transformation.

> The "climate dice" describing the chance of an unusually warm or cool season, relative to the climatology of 1951–1980, have progressively become more "loaded" during the past 30 years, coincident with increased global warming. The most dramatic and important change of the climate dice is the appearance of a new category of extreme climate outliers. The most important change of the climate dice is probably the appearance of extreme hot summer anomalies, with mean temperature

> at least three standard deviations greater than climatology, over about 10 percent of land area in recent years. These extreme temperatures were practically absent in the period of climatology, covering only a few tenths of one percent of the land area. Therefore we can say with a high degree of confidence that events such as the extreme summer heat in the Moscow region in 2010 and Texas in 2011 were a consequence of global warming. (Hansen, Sato, and Reudy 2011,1)

Meanwhile, the government's response several years earlier to a metropolitan water deficit was to build a desalination plant and interbasin pipelines to deal with the decline in rainfall that began in 1998. Despite an enhanced dependency on electricity to carry out these measures, policies built on the efficiencies of integrating water making and power generation were not pursued.

Beginning in 2010, the El Niño event was replaced by a strengthening La Niña that resulted in high rainfall, flash flooding, and steadily rising metropolitan dam levels. Later that year the state Labor government was defeated by the coalition opposition (the Liberal and National Parties), which had promised to abandon the desalination plant, but eventually claimed they were unable to do so because of contractual obligations (Davidson 2011).

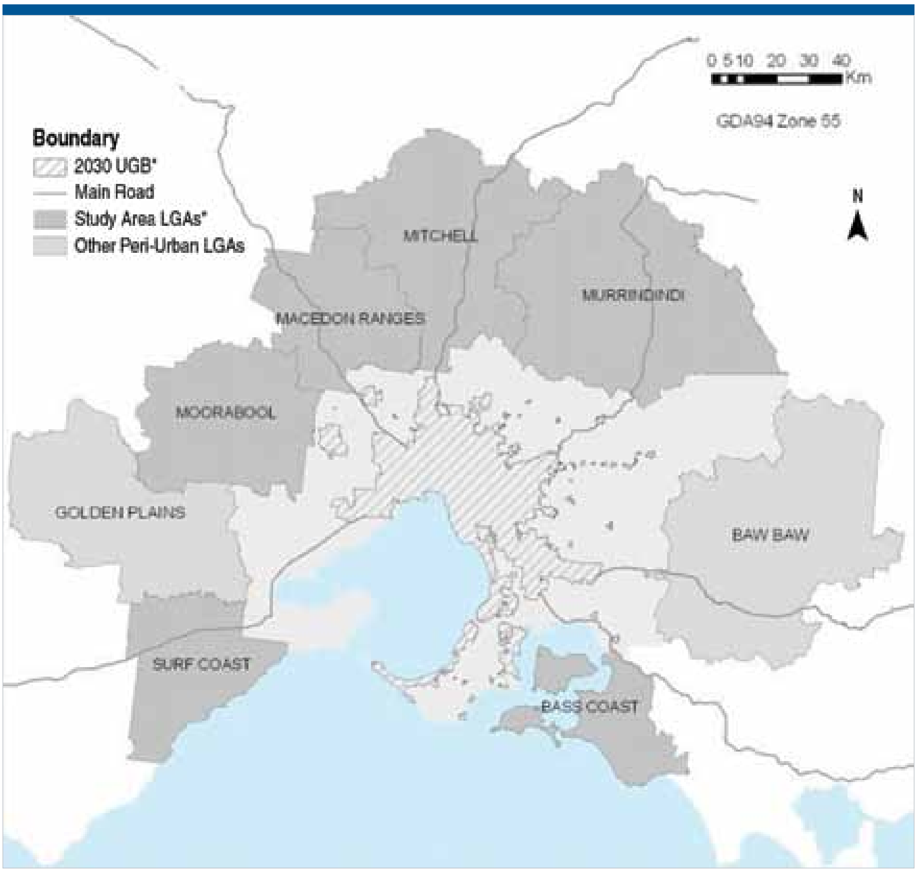
Consequently, this chapter focuses on these two climatic eras—the 12-year drought followed by a period of record-breaking rainfall—that reflect a wild swing in weather conditions considered characteristic of advancing climate change. Victoria's experience at the front lines of that change may offer lessons of value to other places with similar weather patterns, such as Southern California.

The Geopolitical Dimension

Despite being home to fewer than half the inhabitants of London, the Melbourne metropolis covers a larger land area. Its population stands at 4.1 million and is increasing at an annual rate of 2 percent—adding more than 200 people a day or almost 1,500 a week. In 2010, for the ninth consecutive year, Melbourne experienced the highest growth among the capital cities in Australia. Current projections by the Australian Bureau of Statistics estimate the population will swell to between 6.5 and 7.5 million by 2051 (Colebatch 2011).

The metropolis dates from 1835, when an area 10 kilometers (km) upstream from Port Phillip Bay on the Yarra River adjoining a cascade of fresh water of drinking quality above and navigable brackish water below, was chosen by pastoralists from the Launceston-based Port Phillip Associationas a good place to found a village. Development was rapid, and in 1851 a gold rush centered on Bendigo 150 km north and Ballarat 100 km northwest led to a large influx of diggers, including many who came from the earlier gold rush in California. By 1860, 22 main roads radiated out of Melbourne, establishing much of today's arterial road network. This gold-driven boom continued until a depression occurred in 1890. By then, however, "Marvelous

Figure 6.2 Peri-Urban Municipalities Surrounding Melbourne
Source: Buxton et al. (2011).



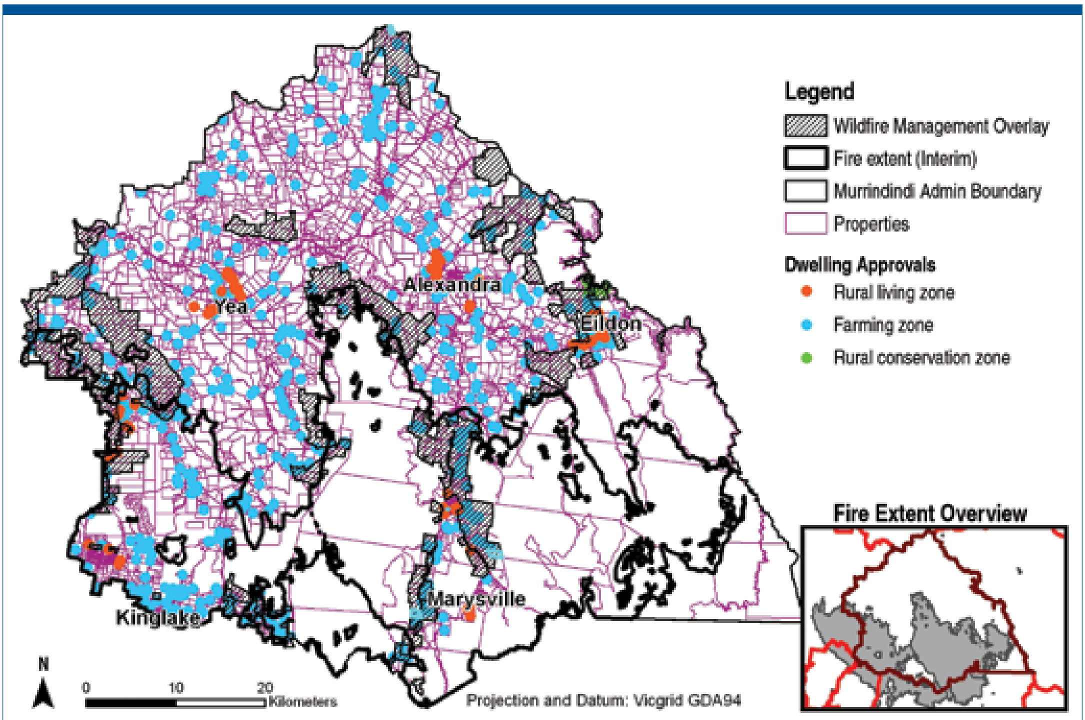
" UGB = urban growth boundary; LGAs = local government authorities."*

Melbourne," as it had become known, had a population of 490,000, making it Australia's largest city.

In the lead-up to the bust in the 1890s, extensive residential subdivisions were built along new railway lines in the eastern half of the city, where the terrain and climate made living conditions more hospitable than areas on the western flank. Regular train services helped to consolidate outlying market towns as housing pushed into intervening spaces and land was cleared for farming, orchards, and market gardens. The 1920s saw the rapid spread of motor vehicles, but continued growth was stunted by the Great Depression and World War II.

By the end of the 1940s Melbourne's population had reached 1.3 million residents. Car ownership, the establishment of wide, paved highways, higher disposable incomes, and shorter working weeks acted to bring formerly isolated areas within easy reach and made them ripe for housing. In 1971 the Melbourne and Metropolitan Board of Works—the authority charged with metropolitan planning—adopted a green-wedge-and-corridor development format for city growth,

Figure 6.3 New Dwelling Approvals in Murrindindi Shire, 1997–2007
Source: Buxton et al. (2011).



a pattern that largely persists, but has come under pressure from successive governments to rezone incremental sections of green acres to accommodate Melbourne's population growth.. Over the years, administration of statutory planning schemes to implement the green-wedge-and-corridor provisions has been shared among local councils and state agencies, depending on which issues the Victorian government considered to be of state significance. In a new twist the coalition government has requested green wedge councils to nominate land for potential inclusion within a revised boundary to overcome "anomalies." Of the 11 councils, 8 have rejected any changes to Melbourne's longstanding green wedges or failed to make submissions by the deadline (Whitelaw 2011).

In 2010, almost half of the city's population lived in suburbs lying more than 20 km from the central business district (figure 6.2). An estimated 600,000 people now reside in the high-risk, fire-prone, peri-urban areas, and many of them commute to jobs within the built-out area (Buxton et al. 2011).

The royal commission established to inquire into the Black Saturday fires was told by six different planning and environment experts that rebuilding homes in places such as the burnt-out town of Marysville would be inadvisable. They added that the risk was so great in some parts of Victoria that residential development there should be prohibited, and this ban should also cover new development and new subdivisions in existing areas (Buxton et al. 2011; Gray

The ruins of a house amid choking smoke in Marysville 24 hours after the Black Saturday conflagration, during which 38 people perished in the town while others huddled on a sports oval until forced to flee eastward to Alexandra in a police-escorted convoy of cars, the blaze right on their heels.
Photograph © Keith Pakenham.

2010a). The experts also called on the government to consider buying back some privately owned land in areas at risk for fires. Nevertheless, numerous new building approvals have been and continue to be granted in the heart of the zone ravaged by the Murrindindi firestorm (figure 6.3).

Regional Climate Change Issues

In the years prior to 2006, the policy focus of climate change in Victoria and elsewhere in Australia was limited to mitigation—in other words, reducing greenhouse gas (GHG) emissions. Recognizing, however, that change in the earth's geophysical system is inevitable, as witnessed by an increasing number of extreme weather events in Europe and other global regions, this response gradually expanded to include adaptation.

A report prepared for the Port Phillip City Council (City of Port Phillip 2007) was one of the first attempts to inform Australian local governments of the role they could play in limiting climate change and natural hazard impacts on private and public assets. Another study of Melbourne's Western Port region undertook a similar assessment (Kinrade et al. 2008). Other specialist studies, including those prepared by the Commonwealth Scientific and Industrial Research Organisation, Australia's national science agency (CSIRO 2005),

Hard surfaces cover the alley of a new development in the Melbourne suburb of Brunswick. Photograph © Peter M. J. Fisher.

examined the water, sewerage, and drainage systems of Melbourne, and a report by Victoria's Department of Sustainability and Environment (DSE 2006) investigated the vulnerability of infrastructure.

During three consecutive days of 43–44ºC temperatures in January 2009, overuse of domestic air conditioners produced power outages with repercussions including disabling the rail network. Rails also buckled on lines not equipped with concrete sleeper ties (NCCARF 2010). The lessons were clear: emergency response systems needed to be improved, design changes made, and some equipment re-engineered to cope with temperature extremes. Rail authorities subsequently undertook some engineering adjustments (Fisher 2009). Extreme heat further affected electricity supplies when a transmission line transformer failed, and the Black Saturday fires a few weeks later threatened the main transmission line to Melbourne and advanced perilously close to the Loy Yang power station and an adjoining coal mine.

Strong population growth in the region's coastal areas has exposed increasing numbers of residents to the threats of storm surge and sea level rise. CSIRO has estimated that between 27,600 and 44,600 homes in the state could be at risk of inundation from a 1.1-meter sea level rise and tidal surge associated with a 1-in-100-year storm. In fact, their research shows that Victoria has the third-highest number of residential buildings at risk of inundation in Australia at a replacement value of $6.5–$10.3 billion* (Department of Climate Change 2009). Of these homes, 70 percent are situated in the Melbourne area, notably the municipalities of Kingston, Hobsons Bay, Greater Geelong, Wellington, and Port Phillip, and by 2016 the coastal population is projected to increase by 92,000. The Climate Commission (2011) has noted that in Melbourne (as well as Sydney), a sea level rise of 0.5 meter leads to very large increases in the incidence of extreme events by factors of 1,000—or 10,000 for some locations.

Some developments or redevelopments close to the sea still had slipped through the planning net, in spite of a sea level rise identified by the Western Port Alliance study (Kinrade et al. 2008) and a new strategy of the Victorian Coastal Council (2008). At least one arm of state government, the Victorian Civil and Administrative Tribunal (VCAT), seemed prepared to grapple with some of the tough implications of climate change in 2008, when it overturned South Gippsland Shire's approval of a six-dwelling planning permit application on the Toora coast. VCAT (2008) conceded that planning for climate change was still in an evolutionary phase and the risk from storm severity would make the proposed developments unacceptable. However, the new coalition government's decision to relieve a council in the state's far west of its controls over development within a zone vulnerable to a 0.8 meter sea level rise suggests a loosening of this approach (Dowling 2011a; 2011b).

Built environments with little space devoted to cooling and the wind-modulating effect of trees continue to emerge in Melbourne although the central city recently has developed a strategy to maintain and enhance trees on its streets and public lands (City of Melbourne 2011). A profusion of heat-absorbing masonry and other hard surfaces that threaten to overload drainage systems when downpours occur has been the norm.

Following a climate change summit in May 2008, a Premier's Climate Change Reference Group was established "to provide expert, independent advice on a range of climate change issues" (Victorian Government Department of Premier and Cabinet 2009, 15). The group focused on mitigation and strongly advocated early action by Victoria in a series of detailed recommendations. Its chairman, Intergovernmental Panel on Climate Change climatologist Professor David Karoly (2009b, 1), made this observation after the group had finished its work.

> The Victorian Government's ambitious green paper on climate change includes discussion of many important actions to respond to climate change through both adaptation and emissions reduction. But the Government appears unwilling or unable to accept that an urgent whole-

* Unless otherwise noted, dollar amounts cited in this chapter refer to Australian currency.

> of-government approach is needed, with limits on population growth, a strategy to phase out brown coal power stations, huge investment in low-carbon energy sources and public transport, and regulations requiring dramatic improvement in energy efficiency.

In 2009 Victoria's government established a partnership with Melbourne, Monash, La Trobe, and RMIT Universities for the Victorian Centre for Climate Change Adaptation Research (VCCCAR). Another development that year was the creation of the royal commission following the Black Saturday fires, which were attributed at least in part to anthropocentric climate change, as was the decline in water storage levels (Karoly 2009a). The new coalition government has since adopted its predecessor's policy of reducing emissions by 20 percent by 2020, but it has abandoned plans to shut down the high-emission Hazelwood power station and permits commercial exploration for brown coal to proceed in the nearby region.

Natural and Man-Made Conditions

A Unique Intersection of Climate and Vegetation

Australia separated from Antarctica 45 million years ago, but the new oceanic circulation opened by the rift affected world climates (White 1994). Although it was no longer contiguous, Antarctica cast a long climatic shadow from the deepest latitudes over its receding neighbor. Even today, research has demonstrated a strong correlation between increased snowfall at Law Dome in East Antarctica and decreased rainfall in the southwestern parts of Australia, and vice versa (AAP 2010; Ommen and Morgan 2010). This derives from two atmospheric moisture corridors: one that blows dry air from the Southern Ocean over southwestern Australia while the other shifts moist air southward to Antarctica. A pressure system that lies between the two continents may be the lynchpin for this atmospheric seesaw.

The resultant drying led to a contraction of the wet Gondwanan forests and their eventual replacement by arid-adapted vegetation, including the progenitor of the gum tree or eucalyptus. Frequent fire was inevitable in this new landscape, and the gum evolved to eliminate competitors in the Gondwanan rainforest by secreting highly flammable oils that encourage ignition, orienting its leaves to reflect sunlight downwards to dry out the understory, and using a shedding bark to start fire ahead of a main blaze. To survive such maelstroms, the trees are able to regenerate from epidermal buds or seed rains, as in the cases of {Eucalyptus regnans} (mountain ash) and {Eucalyptus delegatensis} (alpine ash), both of which are killed by fire.

This is the problematic landscape into which increasing numbers of people have cast themselves since European settlement of Australia started in 1788. The peril to lives and livelihoods was forever present, as demonstrated by the blazes of Black Thursday in 1851, when 25 percent of Victoria is believed to have gone up in flames. However, fewer people lived in the state at that time.

Anthropocentric Climate Change

Victoria's climate has changed radically over the last century, with a pronounced warming since the decade of the 1950s. Research shows one indicator of this trend: indigenous butterflies are emerging from their cocoons 10 days earlier than they did 65 years ago, which correlates with a 1ºC warming (Phillips 2010).

Higher levels of carbon dioxide (CO_2) as well as rain-bearing low pressure systems tracking further south are viewed as playing a key role in the warming over recent decades. This contemporary climate change is increasing fire risk for a growing population, future fires could penetrate Melbourne's generously treed outer suburbs to the east and northeast, causing a death toll that could be counted in the tens of thousands rather than the hundreds lost on Black Saturday. The ferocity and heat of the crescent of fire on that day summons a parallel with the virtually uncontrollable blazes of Southern California in the path of the Santa Ana winds or Mediterranean countries affected by the siroccos from North Africa.

In February 2010, just one year after Black Saturday, epidermal buds of eucalyptus have regenerated in Toolangi Forest.
Photograph © Janet M. Bridgart.

A combination of a marked decline in rainfall resulting in tinder-dry conditions, a location at the end of a 2,000 km northwesterly wind trajectory over the hot, baking deserts of Central Australia, and an abundant tree species that deliberately promotes fire, thrusts Victoria into the front line of climate change. Flame-gas heights during the Murrindindi fire on Black Saturday, for example, exceeded 100 meters and burned at temperatures of 1000ºC or greater. This fire triggered a thunderstorm with lightning over the Mt. Riddell blaze near Healesville, which suggests it created its own microclimate on a day of record low humidity. By contrast, the impact of the drought and rising aridity had been creeping and was far less traumatic. Yet the two phenomena were closely related: the greater the desiccation, the higher the risk of fire and its heat and ferocity.

Grasping the Intricacies of Melbourne's Climate

South Eastern Australia's weather derives from a complex interplay of four main climate drivers: El Niño–Southern Oscillation (EN–SO), the Indian Ocean

At Lake Mountain, the aftermath of the Murrindindi fire revealed pyrolized and gasified leaves, a result of extreme radiant heat.
Photograph © Janet M. Bridgart.

Dipole (IOD), the Southern Annular Mode (SAM), and the Subtropical Ridge. El Niño events arise from sea surface temperatures in the central and eastern tropical Pacific Ocean that are warmer than normal and linked with an anomalous atmospheric circulation called the Southern Oscillation (Mullen et al. 2010).

Both El Niño and La Niña events normally last for about a year, but they can be shorter or much longer. There have been four recent La Niña events: 1998–2001 (moderate), 2007–2008 (weak to moderate), 2008–2009 (weak to moderate), and 2010–2011 (very strong; figure 6.4). In Victoria, El Niño events typically result in reduced rainfall from March to November.

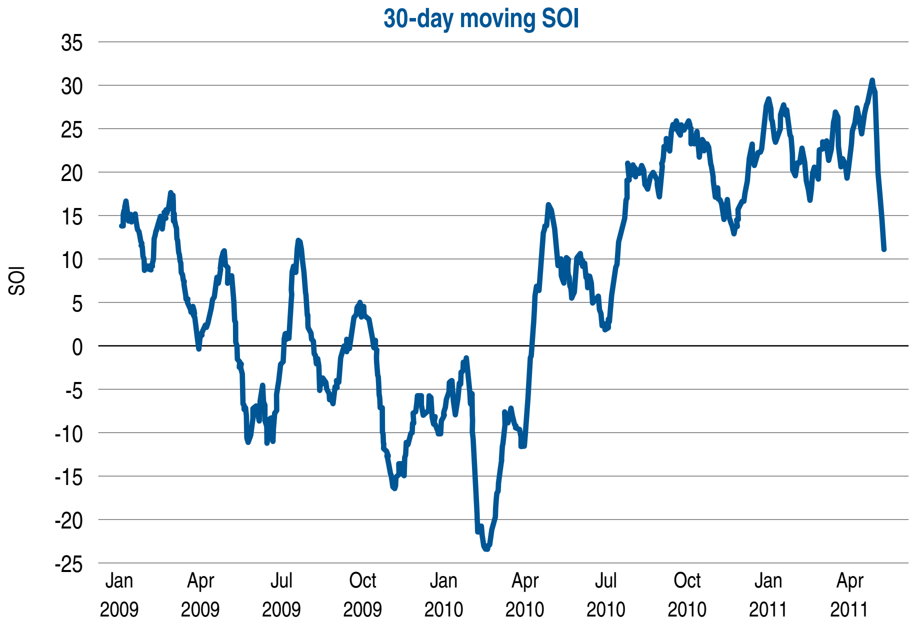
The IOD, a relatively recent discovery, arises from a difference in sea surface temperatures near Africa compared to those near Sumatra and Northern Australia. A positive phase of the IOD is associated with decreased rainfall over southeastern Australia from June to November.

Roger Jones (2009) believes that climate change is implicated in blocking highs and SAM intensification, and perhaps the IOD as well. Natural climate variability also may be interacting with these changes. He records that from the period between 1996 and 1998 until 2010 a statistically significant shift occurred in mean annual rainfall, mean annual stream flow, and mean daily maximum temperature. The annual rainfall decreased by 21 percent, with the largest decreases in spring (23) and autumn (29), next in winter (18), and least in summer (13). For stream flow, the annual decrease was 39 percent and the largest seasonal decrease has been in autumn (46), with the least in spring (35). Maximum daily temperature rose annually by 1°C, increasing 1.2°C in spring and summer, 0.7°C in autumn, and 0.8°C in winter.

Interestingly, in southeastern Australia returns to earlier La Niña events from 2000 to 2009 had not resulted in a resumption of plentiful levels of winter and spring rain, partly because the IOD generally has been in a positive phase during the events. As a result, there was no let up in dryness from late 1996 until the start of 2010. In its negative phase, the IOD brings warm water to the north coast of Australia, which results in increased evaporation into the atmosphere and rain-bearing air sweeping over the continent. It remained gener-

Figure 6.4 The Southern Oscillation Index (SOI) Demonstrates the Strength and Duration of La Niña Events

Source: National Climate Centre; © Commonwealth of Australia, 2011.



ally positive for three years, from 2006 to 2009, even though such a three-year sequence is rare. The major decrease was in autumn rainfall, thought to be due to the more intense central air pressure of the subtropical ridge (Timbal 2010).

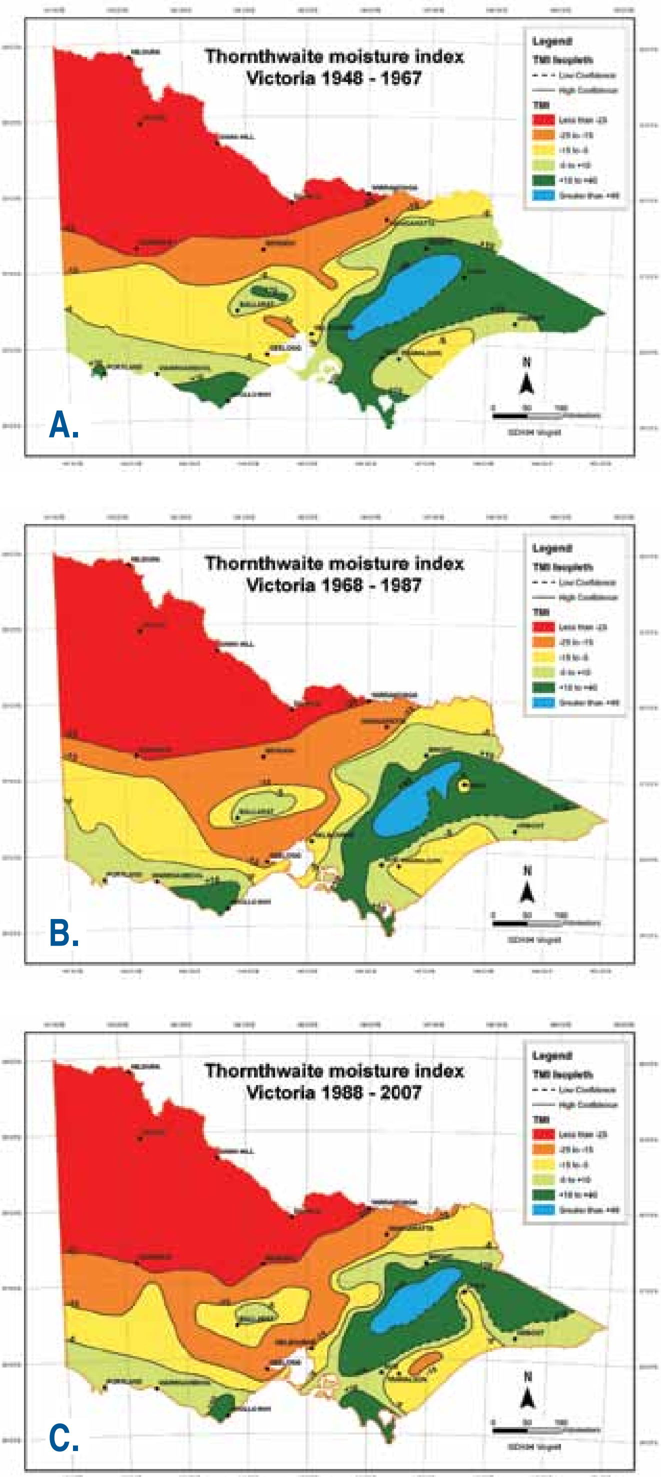
With a La Niña event well established in the Pacific Ocean, however, 2010 saw a wetter weather pattern emerge, and it grew to major proportions by early 2011. Among the ramifications was a "tropical link," with one particular cyclone moving inland from the Coral Sea then tracking south as an intense low pressure system. This produced subtropical conditions and culminated in vast flash flooding in Melbourne and extensive flooding elsewhere in the state's northwestern areas during January and February. Despite these developments, the long-term conditions that led to decreased rainfall since 1996 are still believed to be operative (Roger Jones, personal communication, 2010).

Increasing Aridity and Bushfires: Desiccation, Heat, and Destruction

The extended period of drought in Victoria ended with the "big wet" of 2010–2011, but the drought had exacerbated what was already a steady decline in soil moisture from as early as 1968, as determined by the Thornthwaite Moisture Index (figure 6.5). Apart from the soils in its eastern suburbs, the moisture content of Melbourne's soils equaled that of the drier Bendigo region (just over the Great Dividing Range to the north) earlier in the study period from 1948 to

Figure 6.5 Soil Moisture in Victoria, 1948–2007 (Thornthwaite Moisture Index)

Source: Lopes and Osman (2010).



2007. In other words, for years the metropolis and its peri-urban areas had been succumbing to desiccation and the consequent elevation of fire risk.

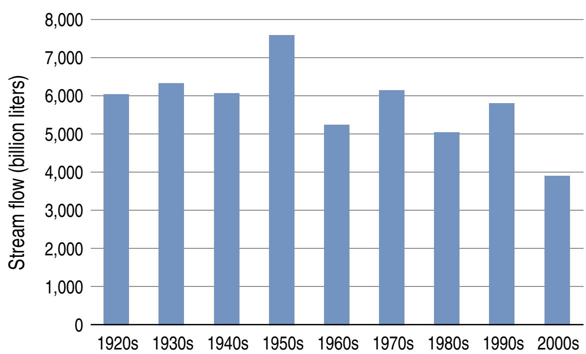
In general, until there is enough rain to dampen the whole system, rainfall refills the soil profile and trickles into groundwater with less run-off. In turn, stream flows are reduced significantly. Thus, a 10 percent decline in rainfall on Melbourne's drinking water catchments over the period of the drought resulted in a 30 percent reduction in inward stream flow (figure 6.6). Dam levels dropped from nearly full in 1996 to barely one-quarter full in 2009, with a steep reduction in the amount of water that flowed into the city's major reservoirs. Increased rainfall in 2010–2011 caused the overall dam levels to rise to two-thirds capacity, while the major Thomson Dam reached 50 percent capacity.

These variables of soil moisture and rainfall also have bearing on low levels of relative humidity. The dry heat typical of summers in Victoria brings about humidity levels that hover around 10 to 20 percent. The low humidity is exacerbated by wind changes accompanying the passage of cold fronts, which increase the dehydrating effects of high winds in the form of hot northerlies that follow. These have become more intense in recent years.

In the 1960s the interplay of weather conditions was integrated into the McArthur Forest Fire Danger Index (FFDI or simply FDI), an empirical indicator of high and extreme fire danger and the relative difficulty of putting out blazes (Karoly 2009a). The FFDI is used for rating fire danger culminating in public warnings for high (FFDI 12–25); very high (25–50); and extreme (>50). An extreme rating is accompanied by a total ban on fires. A report prepared for the Bushfire Cooperative Research Centre indicated that values may substantially exceed 50 (Lucas et al. 2007, 2).

Figure 6.6 Changes in Stream Flow in Melbourne's Water Catchments

Source: Melbourne Water.



> The annual cumulative FFDI values mask much larger changes in the number of days with significant fire risk. The daily fire danger rating is "very high" for FFDI greater than 25 and "extreme" when FFDI exceeds 50. Two new ratings have been defined for this report: "very extreme" when FFDI exceeds 75 and "catastrophic" when FFDI exceeds 100. The number of "very high" fire danger days generally increases 2–13 percent by 2020 for the low scenarios and 10–30 percent for the high scenarios. By 2050, the range is much broader, generally 5–23 percent for the low scenarios and 20–100 percent for the high scenarios. The number of "extreme" fire danger days generally increases 5–25 percent by 2020 for the low scenarios and 15–65 percent for the high scenarios. By 2050, the increases are generally 10–50 percent for the low scenarios and 100–300 percent for the high scenarios.

In the wake of the Black Saturday fires, two additional warnings, extreme (FFDI 75) and catastrophic code red (>100), have been adopted across the continent. The official advice for code red is, "if you live in a bushfire prone area the safest option is to leave the night before, or early in the morning" (Gray 2010b, 7).

Heat, Fire, and Water: Challenges and Experiences Under El Niño Conditions

Soaring Temperatures and Firestorms

Recent incidents. On Saturday, 7 February 2009, temperature records were rewritten across the state of Victoria. The hottest place was Hopetoun in the northwest, with a new statewide benchmark of 48.8°C. In Melbourne, the

Roadside fire alert signs such as this one at Trafalgar, Victoria, show the six risk categories. As a result of Black Saturday, these signs now dot rural Australia.
Photograph © Peter M. J. Fisher.

maximum was 46.4°C, more than three degrees hotter than on Ash Wednesday in 1983, the day holding the previous February record. The FFDI reached unprecedented levels, ranging from 120 to more than 200, and relative humidity plunged down to 6 percent following a week of record temperatures in late January, during which 374 infirm and elderly citizens died from heat exposure.

But the scene had been set well before 7 February dawned. A day earlier, V-Line, the regional passenger train provider, warned of a possible cessation of service on the Gippsland line due to the prospect that the Bunyip State Park fire could flare up and cut off the tracks, which subsequently occurred. Services were also cut on the Seymour and Warrnambool lines. As many as 400 fires were recorded around the region.

A blustery, cool change later in the day swung the wind direction 90 degrees, converting initially long, narrow fire fronts into wide ones that moved in a northeasterly direction, with spot fires flaming up as far as 20 km ahead.

The main blazes were the Kinglake-Murrindindi, Bunyip, Churchill, Bendigo-Redesdale, and Beechworth complexes. The first two were in the greater metropolitan area while the third threatened the state power supply. The fourth penetrated the western suburbs of Bendigo, a provincial city of 100,000 people, and burned to within two km of the central business district.

This ominous occurrence brought the Kinglake-Murrindindi blaze precariously close to the heavily populated, leafy suburbs of outer Melbourne—Eltham, Greensborough, St. Helena, and Warrandyte (Bachelard 2009). The

These ruins of a house and car in the aftermath of Black Saturday's Beechworth blaze were typical of the devastation. One can recognize the random selectivity of the fire's damage, however, by contrasting the relatively untouched oak tree to the left with the scorched, leafless one on the right.
Photograph © David Bethell.

Kinglake-Murrindindi fire complex, which resulted from the merging of separate blazes after a wind change in the late afternoon, killed 159 people and destroyed 1,800 homes and 330,000 ha of land.

After the wind change, the fire turned toward the town of Marysville in the evening, where 38 lives were lost. Temperatures were so high (up to 1,200ºC) that burned vehicles' engine blocks were melted, and forensic teams had great difficulty identifying many victims. It was later determined that 173 people had perished across the state. The destruction of convention facilities, bed and breakfast inns, and other visitor attractions has severely limited the economic recovery of Marysville since the fires.

Black Saturday also showed that Melbourne's surface water supply was in jeopardy, not only from growing aridity but also from serious contamination of its catchments due to burnt vegetation. The Kinglake-Murrindindi Complex South fire broke into the O'Shannassy River and Armstrong Creek water catchments on Tuesday, 10 February. Heavy rainfall in its wake would have caused mud, ash, soil, and rocks to be washed into the dams, something that occurred after the January 2003 fires in Canberra.

Policy responses. Victoria's premier, John Brumby, visited the ravaged towns on 9 February 2009, when he announced that a royal commission would examine "all aspects of the government's bushfire strategy including whether climate change contributed to the severity of the fires" (Australian Broadcasting Corporation 2009). Touring Marysville, Buxton, and Kinglake with Brumby on 17 February 2009, Kevin Rudd, then Australia's prime minister, declared that communities wiped out by Victoria's bushfires would be rebuilt "brick by brick" (Nicholson and Rood 2009). Edward Blakely (2009, 11) publicly cautioned against such assertions, observing:

> It makes little sense to build back into trouble. But in too many instances the desire to build back soon overwhelms the need to build new safer and smarter systems that can withstand foreseeable hazards like climate change. In New Orleans we are learning from the Dutch how to build a city less dependent on levees to secure a better and more sustainable city. Victorians can and should learn from Canberra's disaster as well as identify best practices globally as it rebuilds its communities.

On 10 February, the national and state governments together established the Victorian Bushfire Reconstruction and Recovery Authority to oversee and coordinate a recovery and rebuilding program. Its priority was to "help regions, towns and individuals to rebuild and recover in a way that is safe, timely, efficient, cost effective and respectful of those different needs" (FRU 2011). This authority was also charged with distributing a large amount of money, food, and household items collected for bushfire victims.

Meanwhile, weather predictions, including very strong northerly winds followed by a blustery change, caused the people of Victoria to brace for another maelstrom on 3 March. The police department sent text messages to nearly 3 million cell phones, reportedly as a test for a new telephone-warning system. Fortunately, it was a false alarm, although some adverse comments arose, charging the department of "crying wolf."

The royal commission began its hearings in April 2009. Jack Rush, the counsel assisting the commissioners, took early aim at the alert the public had received before the Black Saturday fire, stating: "The only warning on the day was for an extreme fire danger. Such general warnings [are] not a trigger to go early.... Australian states allow people to make a choice about whether to stay or go rather than requiring them to evacuate. In other countries with a high wildfire risk, evacuation is still seen as the safest emergency approach" (*The Age* 2009, 1).

Under prior government-endorsed fire plans, the *stay-and-defend-or-go* (abbreviated to *stay or go*) policy assumed it was possible for a well-prepared resident to defend a property. The Australian design standard AS 3959-2009 (Construction of Buildings in Bushfire Prone Areas), in particular, holds that properties can be constructed "that will give a measure of protection to the building occupants [until the fires passes] and to the building itself." Clearly, many of the buildings destroyed on Black Saturday did not meet this standard,

Table 6.1 Comparison of Actual Conditions with Design Assumptions of the Australian Standard (AS) 3959-2009

Source: Grundy (2009).

Parameter/Case	AS3959-2009	Australian Capital Territory 18 January 2003	Victoria 7 February 2009
Air temperature	35°C	37.4°C (12:42 pm)	46.4°C Melbourne
Wind	34 km per hour[1]	78 km per hour (gust)[2]	>100 km per hour
Relative humidity	25 percent	4 percent (4:30 pm)	6 percent
Rate of fire spread	3 km per hour	unknown	8 km per hour

Notes:

1. Only used for calculating rate of fire spread in scrub or scrubland, not in forest or woodland.

2. A 14 km high cumuliform plume of dry, unstable air above the ACT fire caused gusts exceeding 100 km per hour and storm damage before and during the firestorm. Gusts in the Kinglake and Marysville firestorms are believed to have been even stronger.

which was developed for conditions prevailing during the Black Friday fires of 1939. The contrast with actual conditions in Victoria is stark (table 6.1).

It appears that AS 3959-2009 assumed an FFDI of 100, but in Victoria on Black Saturday it ranged from 120 to above 200. Whereas it is not uncommon for impact variables to exceed design standards with earthquakes, for example, this analysis indicates that the design standard may need to be reviewed. The royal commission recommended that people should be encouraged to use shelters, the government should cease telling people that houses are safe, and evacuation should be the primary option (Victorian Bushfires Royal Commission 2009a). Even if the former prevails, as Grundy (2009, 3) points out that:

> the areas not burnt this time will be more at risk from bushfires next summer than the areas which were burnt. Although the burnt areas will be rebuilt to a more robust standard of fire resistant structures they will remain vulnerable with even the most fire resistant structure being at risk of destruction, as was demonstrated on Black Saturday. Within the burnt area there are many surviving houses, including timber clad houses, which also remain vulnerable. Accordingly, a risk reduction plan needs to be developed for the unburnt areas where it is likely that only minor modifications to buildings at risk will prove economically and socially acceptable. The same plan should apply to areas recently burnt.

The places not affected on Black Saturday should be given as much concern as the devastated areas. Whereas only 38,000 people permanently reside in those towns that escaped the fire, hundreds of thousands visit or vacation there in the summer months. Melbourne University bushfire researcher Kevin Tolhurst has articulated the perils they could face.

> Fourteen towns not burned out on Black Saturday—from Lorne and Aireys Inlet to the west of Melbourne, through Macedon, Warrandyte and Hepburn Springs, to the Dandenongs and Arthurs Seat in the east—could be disasters waiting to happen. These were examples of how dangerous some places in Victoria could be. Those on top of ridges were in danger of blowtorch-style fires which moved quickly up forested hillsides. Kinglake was devastated by a *blowtorch* fire. Other towns at risk were in hollows or open valleys and in danger of firestorms caused by a blizzard of embers falling from surrounding hills, such as happened in Marysville. The nature of the fuels and terrain in many of these places is what makes them so attractive [to live in] but also potentially disastrous as well. Other dangers were lack of access roads, transient populations, and houses built to capture tree-top views rather than to withstand bushfire. (Bachelard 2010a, 7)

It also is not beyond the bounds of possibility that fires will reshape the vegetation of these areas.

> Eucalypt woodlands would hold on in large areas of their current range, but even these fire-tolerant systems would be vulnerable to big, frequent fires, especially when El Niño droughts compound the effect of global warming. Fragmentation of ecosystems would limit the ability of plant communities to colonise more hospitable areas. Plants have to occupy intermediate zones. Migration isn't likely. (C. Jones 2010)

Heavily forested "tree change" communities at the periphery of the metropolitan area, such as those in the Dandenong Ranges and North Warrandyte, are set in a maze of winding roads and dirt access tracks that quickly would become jammed with escapees. Similarly, in the coastal towns of Lorne, Aireys Inlet, Fairhaven, and Anglesea, an area destroyed by fires on Ash Wednesday in 1983, the forest has grown back and residents and summer numbers have ballooned, but the overcrowded Great Ocean Road remains the only way out.

Bushfire behavior is so complex it thwarts the type of fine-grained risk assessments needed to distinguish between what is probable and inevitable. The VCAT recently refused to grant permission for a family to build a house on its Yarra Valley land, in part because the tribunal thought the risk of bushfire was too great and the site fraught with danger (Cooke 2010). However, contemporary historical research on brushfires in Southern California could help Australia with an application of a computer model that predicts risk in narrow bands across a terrain according to spatial variation in extreme winds (Moritz et al. 2010).

As noted above, the royal commission examined the provision of safe refuges, but the government has yet to identify fully where these places may be situated in towns throughout the state (Lacey 2009; Victorian Bushfires Royal

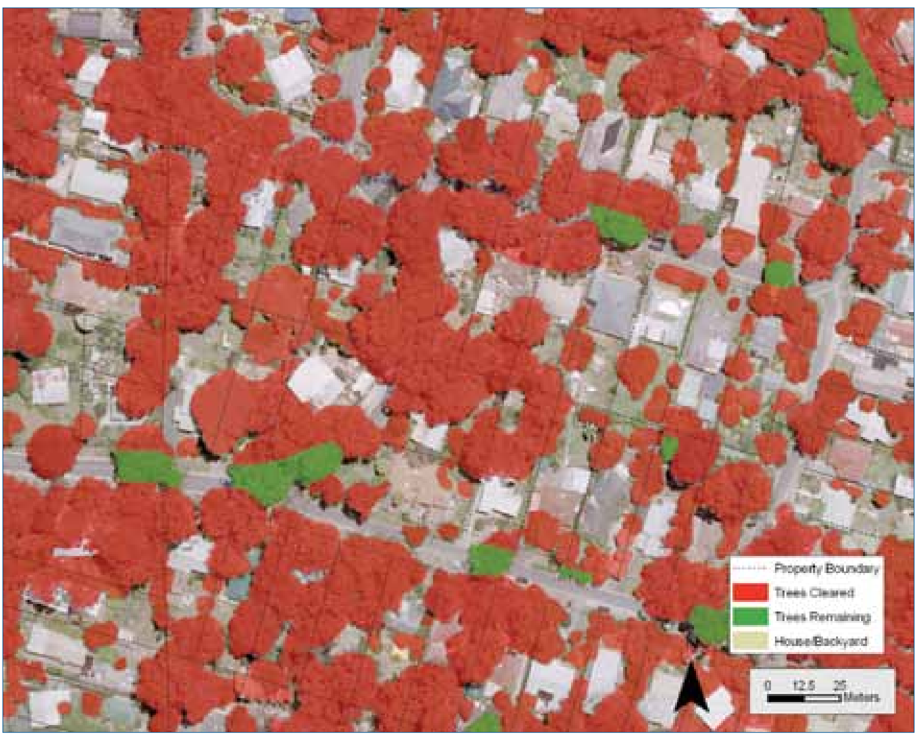
Commission 2009). The commission recommended that the term *neighborhood safer place-place of last resort (NSP)* be abandoned in favor of *shelters*. This has not occurred, and NSP signs are already beginning to appear with the release of maps designating 85 percent of the state as bushfire prone (Dowling 2011b).

Fire Services Commissioner Craig Lapsley has signaled that in future Victorians will be warned at the commencement of the fire season "that they face a high risk of trauma, injury or death" if they seek shelter in a place of "last resort," such as a local sports ground or a farm dam. He also urged parents on "extreme" or "code red" days to take children from schools before the first hint of fire (Gray 2011c).

The very intense fires that were experienced on Black Saturday would have produced a witch's brew of chemicals—aldehydes, volatile organic compounds, and fine particulates—as well as the deadly carbon monoxide that resulted through the reaction of water with elemental carbon. Clearly that level of toxics exposure, which could lead to long-term health consequences, would be better avoided by abandoning the affected areas altogether.

Fuel-reduction burns (FRBs) to eliminate or reduce the severity of fires have always been a point of contention between those wanting asset protection and those who favor habitat conservation. The evidence for the effectiveness of such burns has been very mixed, with the type of vegetation, terrain (ridge lines, etc.), and fire temperature all appearing to be critical variables. Geoff Lacey (2009, 10–11), for example, uncovers evidence from French Island forests near Melbourne "that an open under storey is not necessarily the result of frequent burning . . . [and] that frequent hot burning by settlers in some locations gave rise to a dense growth of trees and shrubs." He further cautions that frequent control burning in forests and other ecosystems "could result in changing the species composition and perhaps a change of the ecosystem from one type to another, for example, from a shrubby to a grassy under storey and vice versa."

A different viewpoint has been offered by a former forests chief, who told the royal commission that, over 30 years, successive state governments failed the people of Victoria by allowing forest fuels to build up to unnaturally high levels, creating fuel loads that significantly contributed to the high death toll on Black Saturday. He also called for tripling the annual FRBs' target to 385,000 ha, which should be mandated in law (Gray 2010b). According to Robyn Grant (personal communication 2011) of the Gippsland Environment Group, however, FRBs as presently constituted suffer from systemic problems that, if not remedied, could lead to wholesale destruction of species and possibly "the bush" as we know it. For example, the monitoring budget provides only 1 to 2 percent of the fuel-reduction budget and includes no fauna, fungi, invertebrate, or aquatic species monitoring. Nor does it accommodate water-quality monitoring. Moreover, the frequency of FRBs allows no time for seeding and regeneration, and the burns are not performed on a trickle-mosaic basis, which tend to be hot rather than cold burns and allow wildlife to take refuge in adjoining patches.



Before and after aerial views demonstrate how few trees would remain untouched (in green on second image) if residents of a 6.4 ha area at Upwey in Melbourne's Dandenong Ranges strictly followed new clearing rules legislated by the government of Victoria in the wake of Black Saturday.
Photographs © Michael Buxton.

No less controversial is the issue of clearing around houses. In September 2009, under the concept of "defendable spaces," the state government issued new rules, which stated that properties can be cleared of trees within ten meters of a house and four meters of a fence line. Given the size of many subdivisions in peri-urban areas, this rule could result in a virtual stripping of the landscape. Michael Buxton's aerial photographs show that, for a 4.6 ha area at Upwey in the Dandenong Ranges, only 12 of the existing 262 trees are safe from being felled. Apparently the only thing preventing this from happening is the expense to the property owner.

Ken Edmunds, a firefighter, has suggested that this kind of tree clearing could lead to fierce winds funneling through the denuded landscapes, spreading fires even farther and faster, and in any event fireballs that result from wind-borne debris could drop on any property (personal communication 2009). Concerns about how to respond to fire danger show up in the Country Fire Authority's (CFA 2009, 4) pre-existing information brochure about leaving early or defending your property: "If you chose to stay to defend, you must have adequate defendable spaces, be well prepared and understand the complexities and the risks of your decision, including *the very real chance you may be injured or killed*" (emphasis added).

A further response to the Black Saturday fires has been to develop a bushfire attack level (BAL) rating system in which homes are categorized in one of six bushfire levels, ranging from low to extreme, based on risk factors including the fire danger index, FFDI, slope of land, and vegetation. For example, the highest rating—BAL-FZ (flame zone)—would apply to the ridge along which Coombes Road runs in Kinglake West, where all homes were destroyed with a large loss of life. Outbreaks can occur wherein temperatures in excess of 1000ºC make it unlikely that even houses conforming to the BAL scheme would be able to survive, however. A key royal commission recommendation that would have instituted a buy-back of properties at high risk (e.g., BAL-FZ) was rejected by the then-Labor government, although the new coalition government has announced a limited, voluntary scheme (Gray 2011a). This has received a mixed reception from Kinglake property owners (Gray 2011b).

Although the burnt areas are to be rebuilt with more robust standards for fire resistance, they remain vulnerable. Even the most fire-resistant structures, especially those that are timber clad, would be at risk of destruction under weather conditions similar to those on Black Saturday. Thus a risk-reduction plan needs to be developed for the areas that escaped burning, where minor modifications to buildings at risk will prove both economically and socially acceptable. The same plan should apply to areas recently burned.

Finally, the royal commission has been told that, even though the government was warned as early as 2000 that cutting costs on power line maintenance could cause bushfires and pose a serious risk to workers and the public, nothing was done (Bachelard 2010b). A class action against the distribution company SP AusNet, SPI Electricity, headed by a former St. Andrews resident who lost her son on Black Saturday, is expected to go before the Victorian Supreme Court in 2012. The company is alleged to have failed to inspect and maintain its single wire earth return (SWER) power lines, which led to a break in a 43-year-old line that started a fire near Saunders Road in Kilmore East (Campbell 2011).

Meanwhile, at the close of 2011 the government announced a $500 million plan over 10 years to implement a recommendation from the royal commission to replace Victoria's 100,000 km of dangerous SWER lines. The government's plan calls for installation of a mix of aerial-bundled lines and underground lines, whereas the royal commission directed running all lines underground at an estimated cost of $40 billion. The government claims that this will reduce by 64 percent the risk of power lines starting a bushfire while achieving a 91 percent reduction from the cost for full undergrounding (Lucas 2011).

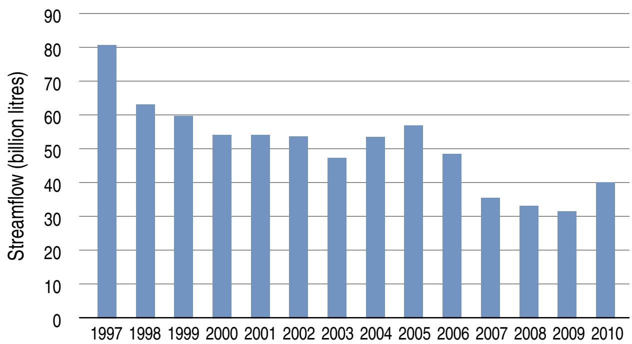
Nonetheless, the Powerline Bushfire Safety Taskforce (2011, 3) noted that "the majority of powerline-initiated fires in Powercor's and SP AusNet's areas in 2009 were started by multi-wire powerlines (typically 22kV): approximately 1.6 fires started for each 1000 km of multi-wire powerlines compared with 0.3 fires started for each 1000 km of SWER powerlines." In that respect, the government has adopted the taskforce's recommendations to mandate installation of rapid earth fault current limiters (REFCLs) that operate on 22kV power lines and new-generation automatic circuit reclosers (ACRs) for use on SWER power lines. Regarding priorities, the taskforce noted that "a large proportion of the state‘s fire loss consequence [the likely extent of damage from a bushfire] can be mitigated by targeting actions to a relatively small proportion of powerlines supplying a small proportion of Victoria‘s rural customers. These powerlines are mainly located in the Dandenong Ranges extending north through to the foothills of the Great Dividing Range, the Otway Ranges and the Macedon Ranges" (Powerline Bushfire Safety Taskforce 2011, 4).

Drought and the Decline in Water Storage Levels

Recent incidents. In contrast to the rapid onslaught of the fires, the drought was a protracted occurrence. A decline in rainfall began in 1998, and a sharp drop in drinking water levels reduced Melbourne's reservoirs to 25.6 percent by mid-2009—the lowest level ever recorded (figure 6.7). Above-average rain from 2009 into 2010 caused a turnaround, with dammed reservoirs refilling after 14 years of drought. Between 23 June 2009 and 21 November 2011, total system storage (TSS) rose 724 gigaliters (gL) representing a rise from 26 to 65 percent. The string of record-low levels set earlier took a corresponding toll on agricultural production. More records were broken when the water levels rose.

Drought implies that the particular state of affairs will come to an end at some point, which will be followed by a return to past rainfall and evaporative

Figure 6.7 Melbourne's Water Storage Levels, 1997–2010
Source: Melbourne Water.



regimes. Modeling undertaken by CSIRO indicates that this is unlikely over the long run, however, since water supply is projected to decline by 3 to 11 percent by 2020 (depending upon the warming scenario) and 7 to 34 percent by 2070 (R. Jones 2009).

David Dunkerley (2009) examined the intricacies of Melbourne's rainfall for 24-hour periods spanning a 68-year timeframe and found a shift to prolonged precipitation events characterized by lower rain rates and smaller event depths, all of which could potentially exacerbate the effects of declining annual rainfall. He further notes that a larger fraction of the incident rain is lost to wet-canopy evaporation during lower rain-rate events. In other words, smaller rain events are less able to penetrate leaf canopies and ground litter to replenish the soil's moisture store, while changes in subdaily rainfall may be of considerable significance to ecohydrology and to the production of water supply from forested catchments. Clearly this phenomenon had been instrumental in the decline in soil moisture observed earlier (Lopes and Osman 2010).

Lower rain rates and smaller event depths have provided conditions for the outbreak of fires within forested water reserves. Fire invaded the Maroondah, O'Shannassy, and Tarago reservoirs on and after Black Saturday, damaging 30 percent of Melbourne's catchments during a period when water consumption trebled. These events showed that surface water supply is not only in jeopardy from growing aridity, but subsequent heavy rainfall can wash mud, ash, soil, and rocks into the dammed bodies of water (the Tarago, Thomson, Upper Yarra, O'Shannassy, Maroondah, Greenvale, Yan Yean, Sugarloaf, Silvan, and Cardinia Reservoirs). This occurred after the Canberra fires and required filtration plant upgrades (White et al. 2006). Additionally, the water demands for recolonizing eucalyptus saplings can deplete runoff for 20 or more years. It was fortunate that only limited rain fell over Melbourne's catchments in the wake of 7 February 2009.

Policy responses. In the weeks following Black Saturday, water held in the storage areas at Maroondah and O'Shannassy, both of which had fire-damaged reserves, was sent to areas where there had been no fire, specifically the Silvan and Cardinia Reservoirs, to guard against heavy rainfall washing contaminants into them (White et al. 2003). Some 500 km of firebreaks 40 meters wide subsequently were cut around the Thomson and Upper Yarra catchments, which supply most of the city's drinking water, to protect 160,000 ha of vulnerable forest, based on the assumption that these efforts would make the catchments closer to 100 percent safe. Airborne burning bark and twigs, however, can ignite areas as far as 20 km ahead of an advancing fire and thus breach these buffers, especially with the kind of temperatures, humidity, and winds experienced on Black Saturday.

The announcement in 2005 that the smaller Tarago reservoir was to be recommissioned was cast as a response to climate change, with the state government remaining opposed to building desalination plants or pipelines to tap into other water basins. The State Government of Victoria's Our Water Our Future initiative (DES 2007) adopted the conclusion of the Melbourne Water Climate Change Study.

> Demand management measures and water supply augmentations identified in the Water Resources Strategy for the Melbourne Area were found to provide sufficient buffer for climate change to be adequate in 2020 across the full range of climate change and alternative demand forecasts considered in this case study.... After 2020 the magnitude of supply side changes may require additional action to be taken including desalination or other system augmentation. Melbourne Water's ability to cope with climate change will be dependent on the rate at which climate change, population growth and water use reductions occur. (Melbourne Water 2005, 18)

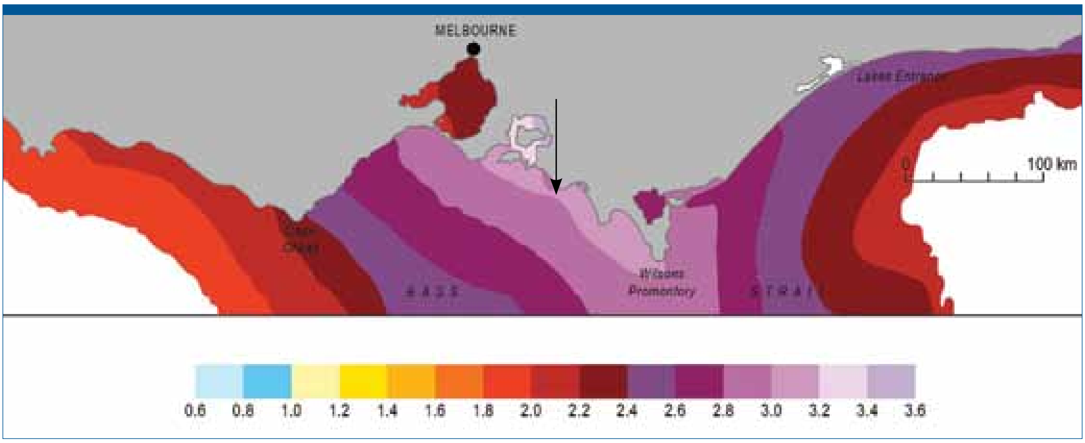
At the time, it was assumed that the drying was a phase and that wetter conditions would return (which, in fact, they did from 2010). Two years after Our Water Our Future got its start, the State Government of Victoria (DES 2007) determined this perspective to be tenable no longer, and it released a water plan, again marketed as Our Water Our Future, settling for big engineering solutions rather than focusing on domestic water tanks and recycling, as many had urged (Parliament of Victoria 2009). Australia's largest reverse osmosis (RO) desalination plant, which is designed to produce 150 gL per annum—or one-third of Melbourne's water needs—remains under construction at Wonthaggi, southeast of Melbourne, a few hundred meters away from a high wave-energy coastline.

Multiple-effect desalination (MED) combined with gas-fired, combined-cycle electricity generation, an alternative method common in the Middle East, was overlooked. Such technologies use the heat exhausted from the turbines making electricity in gas-fired power stations to generate steam that feeds a turbine to make yet more electricity. The steam then can be condensed or sent to a distillation plant to produce freshwater. Combined-cycle installations have impressive fuel efficiencies, both in desalination and in pure power generation modes.

A public-private partnership is building the RO plant near the mouth of the Little Powlett River at a site that is vulnerable to inundation. Flooding that

Figure 6.8 1-in-100-year Storm Tide Height in 2100[1] Relative to Present-Day Mean Sea Level

Source: McInnes et al. (2009; 2011).



In harm's way? CSIRO modeling suggests that the Wonthaggi desalination plant (indicated by arrow) is especially vulnerable to storm surge under conditions of rising sea levels.

1. Assumes a 19 percent increase in winds forcing the storm surge and 82 cm of sea level rise.

took place in 2007 was called a 1-in-100-year event by the state government, for example, yet it disrupted construction work when it occurred again in February 2011 (figure 6.8). Opponents have numerous concerns: the brine load; disruption of rustic values; the need to put the rejected iron chloride used in the process in a landfill; and the plant's dependency, at least in part, on power generated from brown coal. Another problem is its close proximity to the ocean on a part of the southern coast that CSIRO has identified as the most vulnerable to storm surge and sea level rise (Department of Climate Change 2009; McInnes et al. 2009; 2011).

Once the plant comes online, water prices are expected to rise 64 percent, and it is planned to continue producing water until Melbourne's reservoirs reach 65 percent capacity—a TSS level attained on 21 November 2011. When originally announced in 2007, the cost was $3.1 billion, which rose to $3.5 billion after farmers demanded that feeder power lines from the Latrobe Valley that cross their properties be put under ground. Then the winning consortium said that the full cost, including operating expenses, would be $4.8 billion with financing. In late 2009 the government tabled a document showing the cost would be $5.7 billion. Kenneth Davidson (2010, 11) observed, "even if the plant produces nothing, the government will be forced to pay under its contract $570 million a year for 30 years. This is equal to $3.80 a kilolitre without the supply of any water."

The government's 2007 water strategy had another key element: public-private partnerships building pipelines to move water within or between basins, known in current water parlance as a *water grid*. The key pipeline, the North-South or Sugarloaf, was conceived as an insurance policy for providing a supplemental water supply until the Wonthaggi desalination plant came online. It was intended to transport water from a then-depleted Goulburn River (a tributary of the Murray-Darling) to a holding reservoir at Sugarloaf. The pipeline was predicated on a 225 gl per annum water savings further downstream in the Goulburn Valley, primarily because it was expected to eliminate evaporation and seepage losses in irrigation channels as part of a broader "food bowl" plan. The Victorian Auditor-General's Office (2010) has since found that the government failed to demonstrate the need for this expenditure and to properly explore alternatives.

The new Minister for Water has stated that moving water through a water grid from one community to another deprives a farming industry reliant on the water in the former community, however (Walsh 2011). The government has since mothballed the North-South pipeline in favor of emphasizing water security by increasing recycling initiatives for both water and stormwater (Arup 2011). The minister also expressed concern about the water-saving estimates in Northern Victoria and asked the state ombudsman to look at the oversight and governance of the irrigation modernization project there. The ombudsman subsequently reported that the project has "an ongoing battle" with technical problems, poor contractor work, and faulty equipment (Fyfe 2011, 2).

Both the desalination plant and interbasin pipelines represent a shift to carbon-intensive solutions. Forcing seawater through ultrafine membranes or pumping raw water over mountain ranges consumes large amounts of electricity, which translates into even greater emissions and requirements for yet more water for cooling at the power stations. These energy-greedy projects are being superimposed onto existing and planned carbon-intensive wastewater treatments that are struggling to be offset by methane capture, pumping efficiencies, and other measures.

In 2007 the government at the time had maintained that the increased energy demands could be countered by renewables. In Perth, Western Australia, for example, 48 wind turbines were built to compensate for the coal- and gas-fired turbines that powered the Kwinana desalination plant. Fully operational, Australia's fledgling RO water desalination plants could release up to 6,000 metric tons of carbon dioxide emissions from the nation's coal-fired power stations. At this rate, wind farms hardly dent the growth in national GHG emissions.

The change from predominantly gravity-fed potable water supply via mountain dams to volt-driven processes can potentially push the water industry toward an even greater dependency on the electricity sector. That deepening connection requires new organizational approaches to keep abreast of the technological changes. But the lack of technical direction within the state government that resulted from outsourcing appears to have clouded recognition of the opportunities this presents.

The Yarra River discharges its plume of sediment and pollutants into Port Phillip Bay in the wake of massive rainfall during February 2011. Photograph © Mike Abicare.

Victoria urgently needs to retire its less efficient, dirty, brown-coal-fired stations, and the state's former Labor government had sought federal funding to decommission the Hazelwood plant. Early in 2011, however, the new coalition government abandoned that plan. Nonetheless, the introduction of a national carbon price in Australia, which will begin in July 2012, includes a request for expressions of interest by high emission power stations to offer to close down. While Hazelwood has shown interest, it has made no final decision whether to accept a closure offer. Price will play a large part, but inevitably gas base load progressively will replace existing capacity or meet additional demand through a combination of carbon price and banks' reluctance to lend to coal-fired projects.

Given that Victoria earlier faced a water deficit of considerable proportions, which was compounded with the need to move from dirty, low-efficiency, coal-fired power stations toward natural gas, it is difficult to comprehend how the Gulf states' successful model for integrating electricity generation with water making—that is, gas-fired, combined-cycle plants linked to multiple-effect distillation—could have been overlooked had it not been poorly understood. This appears to reflect the fact that energy and water policy development operate in separate silos. Upon such lines, in 2010 Australia's then-Chief Scientist Penny Sackett, referring to her report Challenges at Energy-Water-Carbon Intersection (PMSEIC 2010), expressed doubts as to whether budgets around the nation for energy, water, and carbon were being dealt with holistically. She added that treating one independently could harm the others (Fisher 2011).

In the short term, at least, the existence of the Wonthaggi RO plant appears to have ruled out any consideration of an integrated installation at, say, Hastings on Western Port Bay, which has Longford gas and where brine concentrate could be sent to the Eastern Treatment Plant effluent outfall.

Nevertheless, opportunities remain for smaller water energy projects that scavenge waste heat and/or combustible gases from industrial sites, especially refineries, power stations, and gas plants, to run small MED systems—which are commonplace in ships and sugar refineries—to turn seawater or brackish bore water into process water. These alternatives could, at the same time, circumvent transmission line losses by as much as 20 percent due to the distance between the user and the base-load generator. Wind farms or wave farms, then, could be turned to other uses, thus further lowering transmission line losses. The possibilities are many and varied, and they suggest the scope of effort needed to both ensure water security and limit emissions growth.

Washed Out: Challenges and Experiences Under La Niña Conditions

Recent incidents. Record rainfall during February 2011 resulted in flash flooding in Melbourne. As much as 100 mm of rain fell within 75 minutes in some parts of the city. The impact on the Yarra River—sometimes known as "Melbourne's No. 1 Drain," as it threads through the metropolis and into Port Phillip Bay (Otto 2005)—was especially dramatic, with plumes of fine clay sediments as well as cigarette butts, topsoil, dog droppings, and other rubbish carried off city streets, testimony to the spread of paved surfaces. In addition, beaches experienced elevated levels of *E. coli* resulting from a pulse of sewage released from overloaded mains. The drainage authority, Melbourne Water, admitted that raw sewage was pumped into the city's rivers during this period. The storm was subsequently recorded as a 1-in-500-year event, but drainage systems in newer areas were designed to cope with only a 1-in-100-year event—a national standard clearly in need of review. Testimony to the inadequacy of basing return intervals on past weather records when dealing with climate change was the virtual repetition on Christmas Day 2011 of the 1-in-500-year event of the previous February. Once again, less than one year later, the city was lashed by violent storms, flash flooding, and even a tornado ({The Age} 2011).

Rebuilding older parts of the metropolis at a higher density is leading to vast expanses of paved and other hard surfaces that create urban heat island effects, lowered infiltration levels, and greater runoff. Drainage systems are being challenged by this creep of concrete, masonry, and asphalt—a situation not unlike that in the United States, where paved surfaces now account for an area the size of Ohio (Frazer 2005).

Policy responses. In 2005, the Victorian Auditor-General's Office (2005, 5) concluded that "there was little evidence that effective strategies had been applied to address [the] flooding risks. Because of this lack of progress, metropolitan Melbourne will continue to face significant flood-related damage." The situation has only worsened since that report, with infill housing increasing run-off volumes where hard tarmacs and roofs are displacing garden beds, turf, and trees. An architect who designed a block of three-story apartments in a middle suburb among those earmarked "to maximize development along new and future road based trunk public transport corridors" was ordered to install a large water pump in the basement car park, which would also flood, but he noted that no adequate main drain to absorb high-velocity stormwater was in place (Victorian Department of Transport and City of Melbourne 2009, 6).

A Melbourne Water report has warned that by 2030 the city's drainage infrastructure will be overwhelmed almost twice as often, and the area affected by flooding may be 25 percent larger across most parts of metropolitan area (Ker 2011). This means more of the city will be vulnerable to inundation by 2030, as the same aging drainage system struggles to evacuate water from storms that are expected to produce 30 percent more rain by 2030. Philip Pedruco and Rod Watkinson (2011, 12) conclude, "This change in rainfall intensities may have significant implications on future planning, management and infrastructure. . . . We may need to revise our infrastructure design standards, and some areas currently considered appropriate for development may be vulnerable in the future."

Policy Directions: Aspirations for the Decade Ahead

Reconfiguring large parts of Melbourne to cope with a future punctuated by severe deluges obviously is required. In particular, introducing vegetated areas would help attenuate flows, since trees and shrubs adsorb raindrops on their leaves, their roots soak up further amounts, and grass surfaces allow infiltration. More immediate responses are needed, however, which could include restricting construction of underground shops and facilities, such as car parks, and shifting auxiliary generators from basements to higher levels to lessen risks to communities, businesses, and critical infrastructure in order to aid recovery in the event of flooding. Developing a risk map of the metropolis that covers bushfire and storm surge as well as inundation, could aid in data collection.

Areas developed before the late 1970s are especially vulnerable. Their space limitations make it difficult to retrofit them with features such as retarding basins to store water and guide it into waterways and the sea—although an occasional park or sports oval might be used for the purpose. In more favorable circumstances, much of the discharged water could be harvested after the first flush and thence cleansed.

Billions of dollars will be needed to secure these older areas from the worst impacts of climate change. Unfortunately, in the contest for capital, drainage systems receive low priority compared to infrastructure that is viewed as directly boosting economic growth, such as the federal government's National Broadband Network, despite the fact that its systems can be seriously disrupted by inundation.

A public-private partnership between the government and the insurance industry that funds mitigation of riverine flooding might be adapted to address the cause of city flash flooding. Another possibility is levying an impervious-service charge, such as the one in Richmond, Virginia, and many other municipalities in the United States, "to areas that have been paved or otherwise covered with material that is resistant to infiltration by water" (Richmond Department of Public Utilities 2011).

It also has been suggested that the existing built-out city can yield large areas for renewal, and the Victorian Auditor-General's report (2005) can serve as a forewarning that substantial hidden costs associated with building out may occur in some locations. Developers who see planners as roadblocks should be made to wait while careful assessments of flood risk and storm surge under new weather conditions are studied further and become better understood. For example, Melbourne Water intends "to review the performance of the total drainage system in order to ensure its optimum capacity into the future" (City of Casey 2011).

There is no ready-made solution to protecting lives, assets, and wildlife from firestorms. A relentless urban expansion driven by strong population growth is causing the destruction of valuable habitat, the potential extinction of native birds and mammals, and the loss of food-producing land. Significant levels of densification proposed as a solution are now leading to vast expanses of hard surfaces that create urban heat island effects, lower percolation, and intensify runoff as noted earlier. Far more sympathetic treatments are possible (Fisher 2007).

In many parts of the city fringe the fire risk is so great that residential development there should be prohibited—especially in the absence of provisions for compulsory evacuation ahead of code-red conditions—and this ban ought to extend to new development and the subdivision of existing areas (Buxton et al. 2011; Gray 2010a). Moreover, the possibility of a fundamental shift in vegetation type due to more frequent, hotter blazes and global warming should oblige a more extensive government buyback of privately owned land in all high-risk areas. This should also prompt serious thinking about population growth in such places. The previous state Labor government rejected a voluntary buyback scheme proposed in the final report of the Victorian Bushfires Royal Commission (2010), while the opposition at the time, which since has become the coalition government, said it would implement that recommendation. It has now done so, but on a very limited basis by applying the scheme only to properties affected by the 2009 bushfires, which have yet to be rebuilt, and not to other areas at unacceptably high risk for bushfires(Gray 2011a; Urbanalyst 2011).

The combination of dryness and intensive population growth still besets Melbourne's water security. The Labor government had addressed this situation by building a north-south pipeline and a huge RO plant. Apart from an enormous public debt burden, however, these large-scale engineering projects move the water industry toward an even higher dependency on the generation of electricity, thus increasing its vulnerability to the kinds of power shortfalls predicted for the decade ahead. Even if renewable sources are brought into play, the reliance on electricity seems likely to increase Victoria's GHG emissions. It also highlights the need for a greater degree of integration between water making and electricity generation, which is possible with combined-cycle, gas-fired power stations through MED technologies accompanied by greater organizational integration.

A recent report by the U.K. Environment Agency (2009) suggests that water companies merge with energy producers to create more effective partnerships for tackling emissions. The conundrum for Victoria is that the generators are privately owned whereas the water utilities are public. One way or the other, the local water industry and the government clearly have some work to do if they are to lower the industry's carbon footprint in a significant way. The efficiencies arising from integration of the two sectors should not be underestimated.

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Figure 7.1 **Sydney**

Source: Weiss and Overpeck, University of Arizona.

dark blue overlay areas = low-lying coastal areas of ≤ one meter elevation vulnerable to future sea-level rise

Chapter 7

Sydney

Alan Cadogan

Sydney's world famous harbor is at the midpoint of a metropolis that spreads for 100 kilometers (km) north and south along the Australian coast (figure 7.1). It faces a rising South Pacific Ocean to the east and a hotter, drier landscape, far from cooling sea breezes, on the sprawling inland side, which is expected to become even more sweltering as summer temperatures climb. Like all Australian cities, Sydney faces increased temperatures, variable rainfall, more frequent severe weather, and sea level rise. These climate-related changes will affect urban heat levels, coastal storm surges, bushfires, flooding, drought, water quality, biodiversity, and public health.

The Development of Sydney

Although Aboriginal people have lived in the region for an estimated 50,000 years, by world standards Sydney is a young city. In 1909 when its first metropolitan plan was formulated, virtually all of the city's population lived within a 20-km radius of the harbor downtown, and most residents lived within walking distance of jobs on the wharves and in the small downtown. New electric trams were beginning to open up the suburbs, where comparatively low land values allowed residents to acquire larger plots, but Sydney was still a small, relatively dense city (City Exhibition Space 2001).

In 1945 the New South Wales (NSW) state government established the Cumberland County Council, the city's first and only metropolitan planning authority, to address key issues including centralized employment, overcrowding in inner areas, uncoordinated subdivision, distribution of population, and lack of coordination among government agencies. Its county plan assumed a population of 2.25 million by 1980 and was inspired by British models with a greenbelt at a 20-km radius from the city center, and concentration into outer areas with no provision for satellite growth or decentralization. Following the massive postwar migration over the 1950s, the plan essentially was abandoned. By 1967, Sydney's population was 2.5 million, and growth rates suggested it would reach 5.5 million by 2000 (City Exhibition Space 2001).

Major shifts in the Sydney economy during the late twentieth century saw it move away from blue collar toward white collar jobs, which tended to be less centrally located, while road-based private transportation began to be preferred over public transportation. Despite numerous planning schemes aimed at reducing sprawl and linking housing to employment centers and public transport during this period, successive governments have abandoned each plan. They have preferred to release new land on the city's outskirts for development and to prioritize infrastructure funding toward road projects. The result is a sprawling city with a geographic area equivalent to that of Greater London, but with only half as many people.

Recent decades have seen a significant turnaround in attitudes about the increasing desirability of inner-city living, but Sydney remains predominantly suburban. Like most Australian cities, its self-image is based on low density and an ingrained opposition to urban consolidation and higher-density living, both of which present major challenges to the city's long-term sustainability.

The current *City of Cities* metropolitan plan predicts that Sydney's population will increase to 5.3 million by 2031, thus requiring an extra 640,000 new homes and 500,000 new jobs (Department of Planning NSW 2005). The plan concentrates growth in existing centers to meet the target of ensuring that Sydney's residents do not have to travel more than one hour a day for jobs and other services. More than half of the new dwellings are to be accommodated in existing developed areas. In 2010 the plan was reviewed in the context of increasing federal government interest in planning Australia's major cities. Early indications suggest that Sydney's densification, while gradual, is progressing at a higher rate than the plan anticipated. It is unclear, however, whether this is an emerging trend or merely a result of other factors. The absence of effective metropolitan planning, infrastructure coordination, and governance in Sydney and, indeed, in most Australian cities, is actively debated across all states' capital-city communities and governments as well as nationwide (box 7.1). Despite this plan, the new state government, which received an overwhelming mandate for change in the March 2011 election, has already signaled a lower density target for the existing developed areas of the city and a greater proportion of growth at its fringe.

Recent Climate Change Trends and Predictions

Since 1950, Sydney has experienced warming of around 0.8ºC overall and a drop in annual rainfall at a rate of approximately 55 millimeters (mm) per decade. The Commonwealth Scientific and Industrial Research Organisation (CSIRO 2007b, 5) noted that "although changes in average temperature, rainfall, and evaporation will have long-term consequences for [Sydney], the impacts of climate change are more likely to be felt through extreme weather events. Projections suggest that there will be more hot days, bushfires, droughts, and intense storms." By 2050 Sydney is projected to be hotter during every season, with the greatest warming in winter and spring. Maximum daytime and minimum overnight temperatures are expected to rise 2°C to 3°C (DECC 2008).

Box 7.1 Sydney's Urban Structure and Governance

Area	
Location	Eastern coast of Australia, 35ºS latitude
Built-up urban area	1,687 km² (ABS 2010)
Total area (includes national parks and undeveloped land)	12,145 km² (ABS 2010)
Demography	
Population (2008)	4.4 million (approximately 20% of Australia) (ABS 2010).
Density (built-up area)	2,058 people per km² (ABS 2008)
Economy	
Estimated GDP	$172 billion* (Infrastructure Australia 2010)
Governance	
Provincial government	Authority: State of New South Wales Key responsibilities: public transport, health, education, roads, police, water and energy utilities, major infrastructure, metropolitan planning
Local government	Authority: 38 local councils Key responsibilities (delegated by NSW government): land use planning, local place management, local traffic management, waste management, delivery of local services
Metropolitan government	Authority: None The NSW government administers most citywide activities. Metropolitan representation is by the premier of NSW and the lord mayor of Sydney (leader of the City of Sydney Council representing 26.15 km² centering on Sydney downtown), depending on the context.
Physical	
Geography	Sydney occupies a coastal basin that measures approximately 60 km east-west and 100 km north-south; it is contained by low mountains to the south, north, and west. It has two main geographical regions: the Cumberland Plain, a relatively flat region to the south and west of the harbor; and the Hornsby Plateau north of the harbor, which rises as much as 200 meters (m) in elevation, and is dissected by forested valleys.
Structure	Sydney's downtown extends about 2 km south from Sydney Harbor, the point of the first European settlement in 1788 and the city's dominant economic and cultural center. Other centers developed in a radial pattern during the twentieth century, and a multicentered urban form is emerging. Sydney has 300 suburbs. Demographically and geographically, the city center is situated around 15 km west of downtown.

* *Dollar amounts are in Australian currency, unless indicated otherwise.*

Interactions with complex regional climate systems make the effects of future warming on Sydney's rainfall patterns difficult to predict (Garnaut 2008). El Niño remains the greatest wildcard when projecting the future climate of eastern Australia. CSIRO (2007b) notes that it is difficult to distinguish between natural variability and any contribution of human activities in understanding Sydney's declining rainfall. Within an overarching trend toward drier conditions, rainfall projections are variable, with increases in extreme rainfall likely. Generally, rainfall events are expected to become slightly larger and separated by longer dry spells. Rainfall across metropolitan Sydney is projected to increase by 20 to 50 percent in summer, with a smaller increase in spring, and a projected decrease in winter (DECC 2008). Even if future rainfall is at the higher end of the predicted range, higher temperatures will exacerbate evaporation, which will result in overall drying and loss of soil moisture.

Sea level rise on the NSW coast is expected to increase by 0.91 m by 2100. This includes global sea level rise (0.18 m to 0.59 m), ice flow melt (0.2 m), and effects of the East Australian Current (0.12 m) (CSIRO 2007a). The debate continues, however, regarding the likely extent of sea level rise. While predictions indicate a moderate rise, a disproportionately large corresponding increase is expected for inundation and flooding from high tides and storm surges.

Climate models for Sydney's rainfall indicate the potential for both increases and decreases, so despite these trends and predictions, considerable uncertainty exists. Temperature forecasts generally engender greater confidence than projections for sea level rise and rainfall. Confounding the overall warming trend, for example, 2008 was notably cool in Sydney (BOM 2008). For other climate impacts there is simply a lack of reliable information (table 7.1). On a regional level, there is little or no detailed information about the frequency and severity of storm surges, rainfall extremes, drought, hail, or links to local extremes such as air pollution and flood. It should be noted that whatever climate change scenarios are adopted many IPCC climate change projections to date appear to have underestimated the speed and extent of change.

Community Attitudes Toward Climate Change

Australia's largest-ever community protest for action on climate change was held on 12 November 2009, when an estimated 90,000 people took part in a Walk Against Warming in every major city, including 15,000 marchers in Sydney. But apart from large public gatherings, direct evidence of support for action on climate change is lacking. The recent long drought in Sydney highlighted community concerns about the environment, particularly water issues; however, it is unclear if the community perceives any link between the drought and human-induced climate change.

Table 7.1 Current and Projected Climate Change for Sydney

Source: CSIRO (2007a and 2007b); DECC (2008); Greening Australia (2008); and Preston et al. (2008).

	Present (1990)	2030	2070
Average maximum temperature (July–January)	17–26°C	+0.2–1.6°C	+0.7–4.8°C
Days above 35oC per year	3	4–6	4–18
Days above 40oC per year	0	0–1	1–4
Days below 0oC per year	0	0	0
Sea level rise (cm)		+3–16	+7–50
Average rainfall	1,094 mm	–13% to +7%	–40% to +20%
Extreme rainfall	—	–3% to +12%	–7% to +10%
Summer rainfall (2050)	—	+20–50%	
Winter rainfall (2050)	—	+5% to –50%	
Extreme Winds	—	–5% to +8%	–16% to +24%
Evaporation	—	+1–8%	+2–24%
Droughts per decade	3	–1 to +2	–2 to +6
No of Fire Days			
(high or extreme)	9	9–11	10–15
Solar radiation (Sydney Coastal Councils)	—	–1% to +2%	–3% to +6%

In the lead-up to the December 2009 United Nations Climate Change Conference in Copenhagen, the Danish government initiated a global citizen's consultation across 38 countries. The Australian consultation, held in Sydney, involved 105 citizens, all randomly selected based on their representative demographic characteristics; 13 of them were from Sydney (Atherton and Herriman 2009). The results from Australia indicated that 75 percent of its citizens are very concerned about climate change and a further 20 percent are fairly concerned. In addition, 89 percent supported emission reduction targets by 2020 that were within or above the IPCC recommended range of 25 to 40 percent.

For its Sustainable Sydney 2030 vision, in 2008 the city council conducted its own survey, focusing on Sydney's downtown area and surrounding suburbs. This survey considered community attitudes on a range of issues that included climate change and sustainability (City of Sydney and SGS Economics and Planning 2008). Broadly agreeing with the UN-sponsored consultation, the survey's findings showed that:

- 97 percent of all participants, and 97 percent of the residents surveyed in the city council local area, believe that reducing greenhouse gas (GHG) emissions is an important target for the next 20 years; and

- 62 percent of city council local area residents believe that climate change is a threat to the city, and a further 28 percent feel that, while it is not currently a threat, it will present one for future generations if nothing is done.

Although it appears that Sydney's citizens are concerned about climate change, there is no consensus about what should be done on an individual, metropolitan, or national level. It is also unclear how much Australians are prepared to pay for climate change mitigation and adaptation measures.

Climate Change Issues for Sydney

The majority of the Sydney metropolitan area faces some impact—and in many cases multiple repercussions—from climate change. While coastal communities are particularly vulnerable to sea level rise and storm surge events, urban-fringe communities are particularly vulnerable to the effects of bushfire and heat-related health effects. Vulnerability varies not only from suburb to suburb but from household to household as well (Preston et al. 2008).

CSIRO (2007b) identified climate change impacts for metropolitan Sydney under four broad headings: water, farms, biodiversity, and forests and communities. A study for the region under the jurisdiction of the Sydney Coastal Councils Group (SCCG) examined five impact areas: extreme heat and health effects, sea level rise and coastal management, extreme rainfall and stormwater management, bushfire, and effects on ecosystems and natural resources (Preston et al. 2008). While to varying degrees Sydney is exposed to each of these climate adaptation issues, this chapter focuses on the challenges of heat waves and sea level rise.

Extreme Heat

Among climate-related hazards, extreme heat events arguably are the leading cause of mortality in the developed world. Largely due to their diminished thermo-regulatory capacity, older people, infants, and small children are considered high-risk groups for heat-related morbidity and mortality. Benjamin Preston and his colleagues estimated that due to heat-related causes approximately 176 individuals aged 65 or older were likely to die each year in Sydney, or roughly 40 people per 100,000 (Preston et al. 2008). Significantly, despite widespread findings that elderly individuals are more sensitive to heat events, the team found that "mortality does not simply occur in individuals where death was otherwise imminent, but in generally healthy individuals that would have been expected to continue living for years in the absence of the heat event" (Preston et al. 2008, 21).

Climate change is projected to cause significant increases in both the frequency and duration of periods of high temperature in Sydney. As a result, the region may be one of the more sensitive of Australia's cities to increases in heat-related mortality. It has been estimated that, by 2030, the number of days during which Sydney will experience temperatures above 35°C will double, and it will increase six-fold by 2070. Rosalie Woodruff and her associates projected that this would increase the annual heat-related death rate among people 65 and older from 70 to 239 per 100,000 individuals. When combined with Sydney's population growth, this data suggests the potential for 432 to 1,042 premature deaths due to heat waves by 2100 (Woodruff et al. 2005).

Western Sydney is particularly exposed, because it does not receive the cooling sea breezes that moderate the city's eastern coastal suburbs. When Greening Australia (2008) analyzed climate records from Prospect Reservoir (Western Sydney) and Observatory Hill (Coastal Sydney), it found that temperatures for Western Sydney have increased at more than twice the rate experienced by coastal suburbs or expected from global warming (figures 7.2 and 7.3).

Figure 7.2 Mean Maximum Temperatures in January for Sydney and Western Sydney, 1965–2007
Source: Greening Australia (2008).

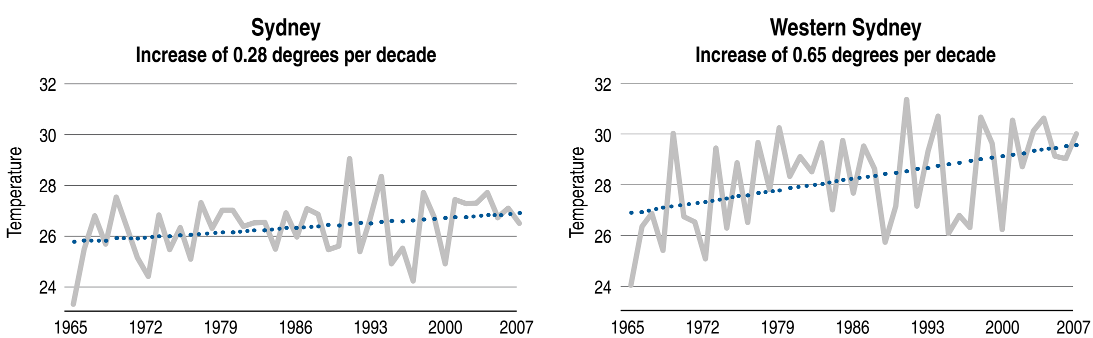
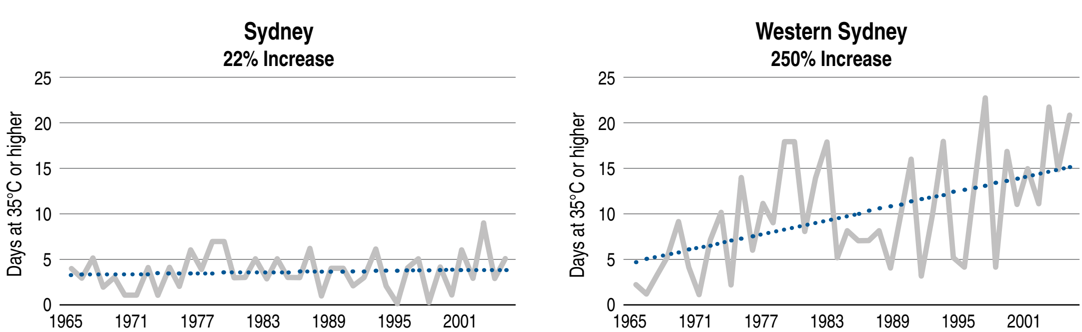


Figure 7.3 Number of Days per Year with Temperatures Greater Than 35°C in Sydney and Western Sydney, 1965–2002
Source: Greening Australia (2008).



Late in the summer of 2011 Sydney experienced its longest, hottest heat wave since records began to be kept in 1858. For more than six nights, the minimum temperature did not fall below 25ºC, while daytime maximums for seven days remained above 30ºC, peaking at 42.2ºC. Richmond, in Sydney's northwest, broke its own record with eight days straight of temperatures at 35ºC and above. Nocturnal discomfort peaked on the early morning of Sunday, 6 February, when a new overnight record for the warmest night in Sydney's history was set—the temperature fell to just 27.6ºC. This heat wave was two days longer than the previous record-setting one. The Ambulance Service of NSW told news media including the Nine MSN news service it had responded to 190 heat-related calls over the course of the heat wave (McGrane and Godfrey 2011; The Age. 2011).

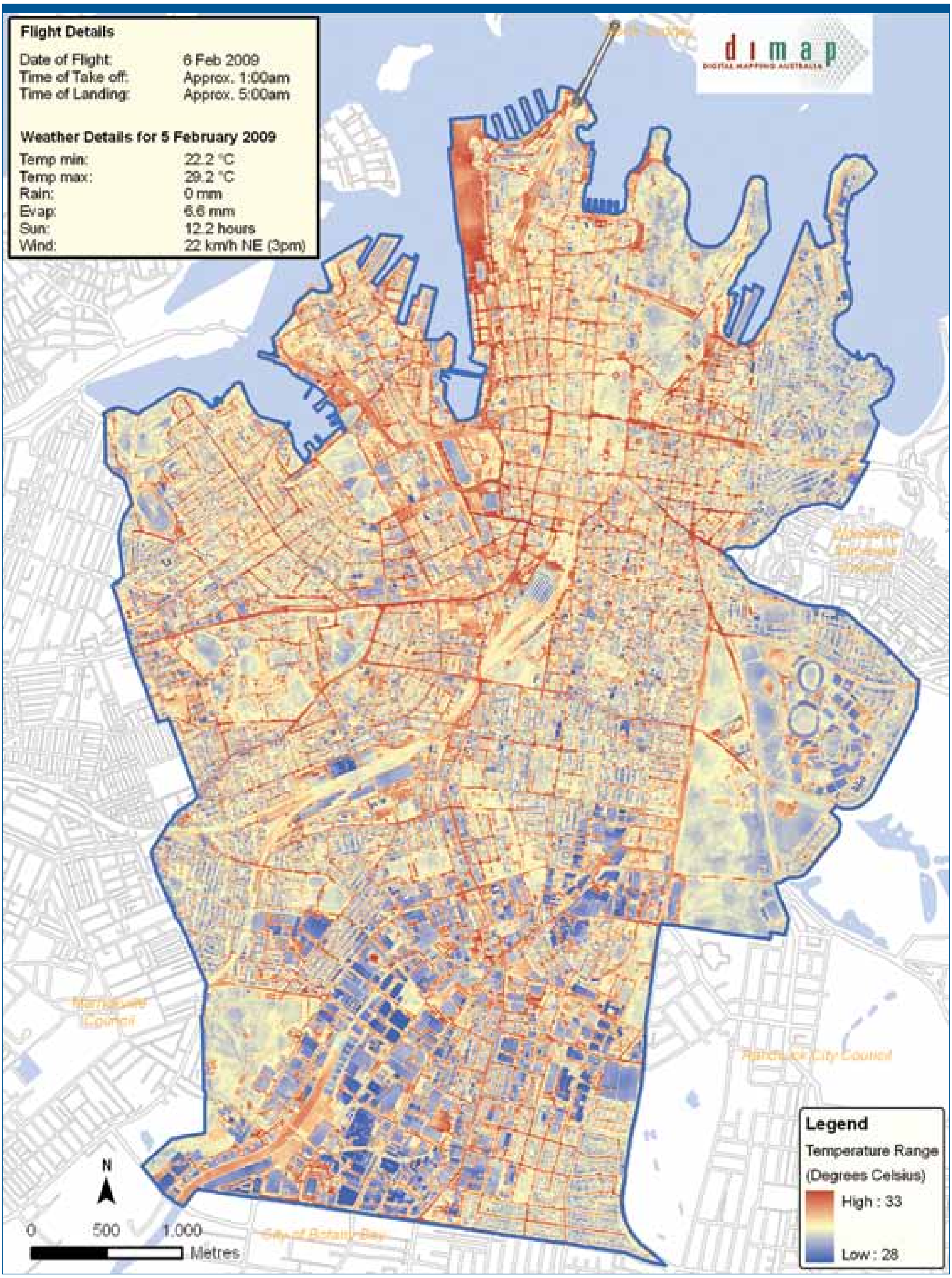
An urban area's thermal environment is highly complex due to the various types of land use, building materials, and infrastructure associated with its landscape. *Urban heat island effect* is a term used to describe localized warming due to urban development and the increase in large amounts of paved and dark-colored surfaces, such as roads, roofs, and car parks. Rather than reflecting the sun's heat, these surfaces absorb it, which causes surface and ambient temperatures to rise. Anthropogenic heat production, such as that from engines, electrical appliances, and air conditioners, also contributes to the urban heat island effect.

A thermal image made between 1:00 and 5:00 a.m. (figure 7.4) encompasses Sydney's downtown area and its surrounding inner suburbs. It clearly compares heat effects brought about by significant areas of dark-colored tarmac, such as major roads and the large port on the western edge of the city center, with those that characterize vegetated areas and white-roofed buildings. Even after several hours of darkness, these darker areas remain up to 7ºC hotter than other areas. John Clarke (1972) found that this effect leads to a nighttime impact of urban heat islands that may actually be greater than maximum temperatures during daytime because higher overnight temperatures do not allow exposed individuals respite from heat. The tendency for higher temperatures, particularly during nighttime, in the more densely developed areas is also found in other cities, such as in Melbourne (Coutts, Beringer, and Tapper 2007). During the 2011 Sydney heat wave, Australia's Bureau of Meteorology figures confirmed the effect, with temperatures in downtown Sydney registering between 1°C and 2ºC higher than those at suburban weather stations.

A study of housing health and safety in the United Kingdom found that heat-related mortality was restricted largely to individuals housed in multiple-occupancy structures, with those living on the top floor particularly at risk (Office of the Prime Minister 2003). These findings suggest that as Sydney's density increases in response to the significant sustainability issues arising from sprawl, a considerable risk of exacerbating extreme heat effects of climate change will increase.

Figure 7.4 Downtown Sydney (Thermal Map)

Source: City of Sydney.



Sea Level Rise

Projections of future sea level rise vary considerably depending on which method is utilized to generate estimates (e.g., global climate modeling simulations, empirical assessment of observations and trends, or paleoclimatic analogy). The various components of sea level rise incorporated (e.g., thermal expansion, ice sheet mass balance, and ice sheet dynamics) are also important considerations. Regionally, sea level rise also may vary significantly from global averages. For example, recent sea level trends around the Australian continent have been significantly higher than the global average (Parliament of the Commonwealth of Australia 2009).

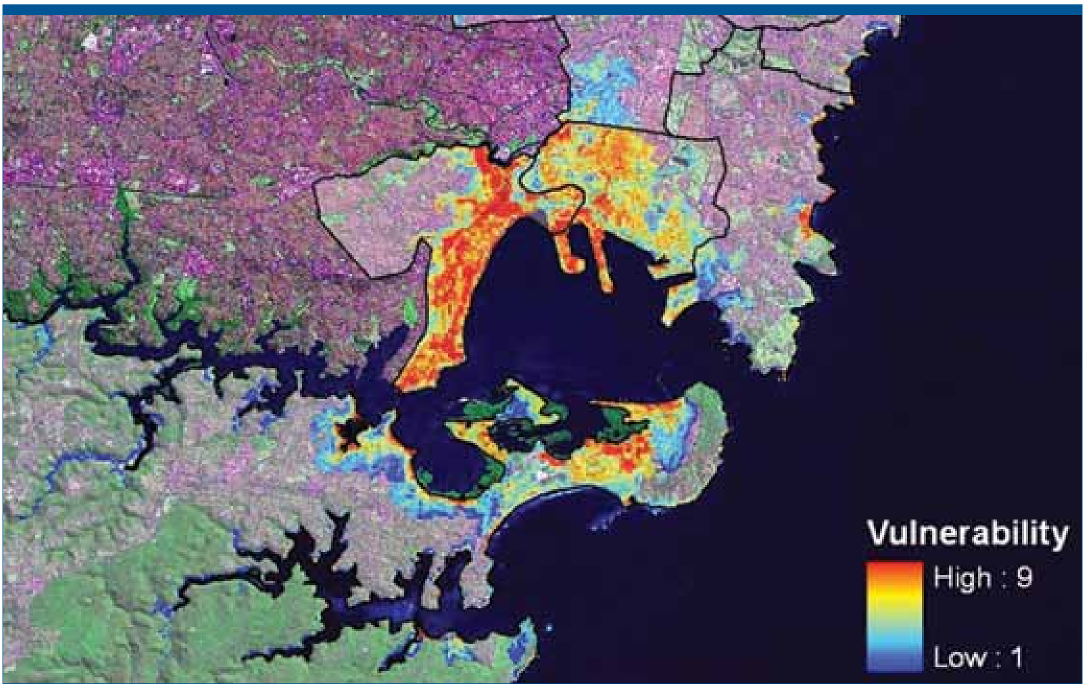
Rising sea levels will increase rates of erosion along susceptible stretches of coastline and progressively inundate low-lying areas. The most significant effect of rising mean sea levels will arise during extreme storm conditions, when strong winds and falling pressure bring about temporary, localized increases in sea level known as storm surges. Those that occur when mean sea levels are higher will enable inundation and damaging waves that penetrate farther inland, causing increased flooding and erosion and subsequent detrimental impacts on built infrastructure and natural ecosystems (Garnaut 2008).

Coastlines' sensitivity to sea level rise and other coastal hazards are highly variable, but their landscape and topography are important factors. The proximity of infrastructure and assets to affected areas is also key. The Department of Environment and Climate Change (DECC 2008, 3) for NSW has recognized that Sydney "has a heavy density of residential and commercial beachfront developments that may be threatened by either ocean inundation or sea level rise induced recession. Settlements adjacent to estuaries and beaches are the most vulnerable." Within the Sydney metropolitan area (Newcastle to Wollongong), 46,000 addresses are identified as being within 1 km of the shoreline and at elevations lower than 3 m (Parliament of the Commonwealth of Australia 2009).

Many of Sydney's critically important cultural, economic, or tourism assets, including the Sydney Opera House, its major oil refinery, and 70 harbor and ocean beaches, such as the world famous Bondi Beach, are potentially threatened by sea level rise and storm surge events. The entire airport, Australia's most significant tourism infrastructure asset, is vulnerable, but its third runway, which was built on reclaimed land only 3 m above sea level and exposed to severe weather on Botany Bay, is at particularly high risk.

In 2009 the Department of Environment and Climate Change estimated that coastal flooding, erosion, and other hazards could cost the NSW government $200 million annually (Parliament of the Commonwealth of Australia 2009). Sea level rise is likely to exacerbate these costs significantly.

Figure 7.5 Coastal Vulnerability for Selected Areas Within the Sydney Coastal Councils Group Region
Source: Preston et al. (2008, 48).



In Sydney's northeastern suburbs, at Collaroy and Narrabeen beaches, coastal erosion is estimated to be as much as 22 meters as a result of a sea level rise of only 20 centimeters. That rises to 110 m in the event of a 1-in-50 year storm surge, with associated economic losses of $230 million (Parliament of the Commonwealth of Australia 2009).

Preston et al. (2008) analyzed the Sydney coastal region in order to determine its net vulnerability to sea level rise (figure 7.5). They found high vulnerability to be a function of multiple challenges, including topography, levels of development, and adaptive capacity.

> As a consequence, assets, infrastructure and coastal amenities (e.g., beaches) in vulnerable areas must be carefully managed in the future to protect both development and amenity. To this end, local governments' adaptive capacities and their ability to partner with each other and state government to achieve management goals may be particularly important. (Preston et al. 2008, 46)

Current Policy Responses

Public Sector Approaches to Climate Change

Even though all levels of government in Australia are coming to recognize climate change as a critical issue, relatively few of their actions in Sydney can be characterized specifically as adaptation to climate change. A 2008 study by the Australian Network of Environmental Defender's Offices identified only seven pieces of legislation at the national and NSW levels that mention climate change (Parliament of the Commonwealth of Australia 2009).

Despite this lack of direct regulation, many existing programs and policies contribute to addressing climate change by means of the broader themes entailed under the heading of sustainability. For example, even though it is not a primary aim of the policy, the NSW government's building code for residential design will help to address extreme heat from climate change through more efficient building design. Similarly, coastal dune protections undertaken since the 1980s to effect sand-erosion mitigation and biodiversity protection at NSW beaches also will help protect against storm surges. Responses to flood management, bushfire, and storm surges already occur, but few of them have been characterized as adaptations to climate change. For Sydney, however, most adaptation responses are likely to involve changes in degree of actions already underway rather than the institution of new actions.

The NSW government's approach to reducing the impacts of climate change is outlined in its greenhouse plan and state plan, and in the climate change action plan it is developing currently. In general, policies are geared toward mitigation rather than adaptation. This reflects recognition of the need to respond to the causes of climate change as well as uncertainty concerning the degree of adaptation measures that might be required. NSW is also working through the Council of Australian Governments, which includes the eight Australian state and territory governments and the national government, to define the scope of national reform required to meet the challenge of adaptation to climate change and identify actions within priority areas.

While cooperation between jurisdictions in Australia is laudable, lack of clear direction at a national level is still considered a problem. A jurisdiction-wide focus on activities, often politically driven and lacking a regional specificity, tends to take hold at the state level, and it often ignores the economic, population, and environmental significance of metropolitan Sydney. As a result, coordination of both mitigation and adaptation policies for metropolitan Sydney is often fragmented or absent.

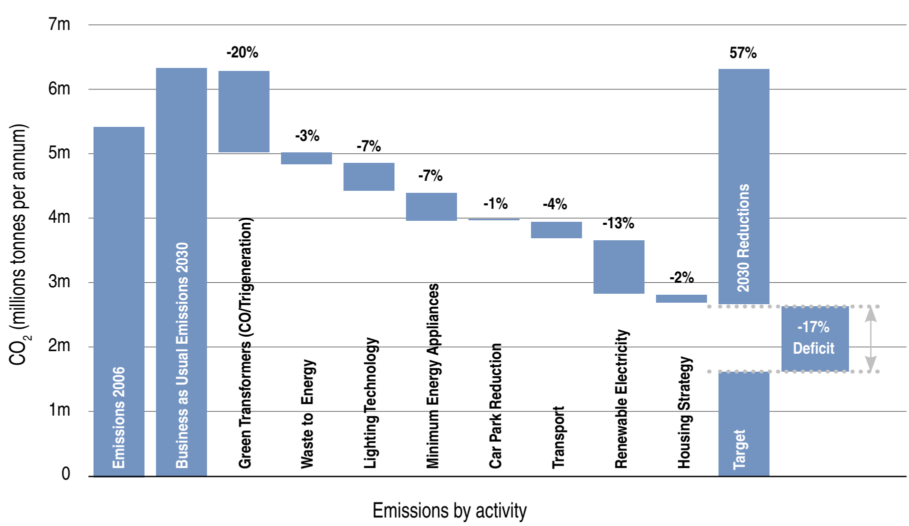
Sydney's local government is charged with responsibility for preparing a range of legally binding statutory planning and land management schemes, including land use plans, codes, and regulations within the state-governed frameworks that can be primary areas in which climate change policy is delivered. Most of the city's local government councils have incorporated some form of sustainability into their land use plans and regulations. They address both mitigation and adaptation actions and are triggered when the councils grant planning consent for development.

Many existing actions by local government, such as planning and management of flooding, bushfire, and drought, are adaptation actions, even though they are not characterized as such. Many Sydney councils have focused other projects or policies toward climate change mitigation. The total number would be too numerous to list, but one key example is Randwick City Council, which initiated a carbon-trading scheme with other councils. In another case, the councils of North Sydney, Parramatta City, and the City of Sydney began CitySwitch, an energy efficiency scheme for office tenants that since has been adopted nationally.

Taking a leadership position in the city's climate change debate, the City of Sydney Council (2008) completed its Sustainable Sydney 2030 vision for the metropolitan region to be green, global, and connected by 2030. Following the largest public consultation ever undertaken there, the work included a broad spectrum of initiatives and objectives that address all aspects of city life and maintain a focus on sustainability. Significantly, the council took an ambitious position in climate change abatement by committing to a 70 percent reduction in GHG emissions from 2006 levels by 2030 (figure 7.6).

Nevertheless, this work by the city council, though significant in terms of its leadership role and empirical contribution, affects just a small part of metropolitan Sydney, whether measured by area or population. It appears that many local governments within Sydney have felt obliged to act locally despite the absence of consistent guidance from national and state governments. Given

Figure 7.6 Sydney's 2030 Emissions Reductions Goals
Source: City of Sydney Council (2008).



the comparatively low level of resourcing available to most Sydney local governments and their small areas, this is problematic. The better-resourced councils have tended to fill the policy gap and do the best they can for their communities. While this can lead to innovation and healthy competitive policy, there is often little or no consistency between councils' efforts and an ineffective, inefficient utilization of public resources from a metropolitan viewpoint.

Private Approaches to Climate Change

Private sector approaches to climate change in Sydney lack documentation. As Ross Garnaut (2008, 364) suggests, "some may expect that government can, and should, protect the community from climate change by implementing the right strategy, program or initiative to allow Australians to maintain established lifestyles. This is not a realistic expectation." It is clear, at least anecdotally, that the climate policy leaders are those multinational corporations or prominent local businesses with self-imposed environmental policies and targets they have derived due to a sense of corporate citizenship and individual responsibility.

Even so, when it comes to climate change the majority of the private sector, as it wrestles with shorter-term investment return horizons, appears to be reactive rather than proactive. The Property Council of Australia and Insurance Council of Australia are among the organizations that represent businesses involved in the development of climate change policy nationally and locally. While other businesses, particularly those responsible for significant emissions, typically oppose policy reform, private sector responses are highly variable. In 2010, for example, as the new national government came to power with a platform including emissions reductions, Australia's largest mining company came out in favor of establishing a carbon price. Perhaps the only unifying element to the debate is that businesses apparently want certainty about the price of carbon. How they may adapt to climate change, other than through mitigation, however, does not feature in current public dialogue.

It appears in many cases that individuals acting alone or as part of small groups are most involved in climate change adaption. They may choose to invest in energy-efficient housing with environmental features, such as passive solar design; locate farther from shorelines in response to potential inundation threats from storm surges; or introduce land management practices, such as back burning or clearing around property assets to reduce fire risk. There is very little evidence, however, on which to draw any firm conclusions about these activities collectively. Anecdotally it appears that, while many people are personally concerned about climate change, few have any clear idea about how it will affect them and what they might do to adapt.

Adaptation Responses to Extreme Heat

Sydney's two major climate change issues of extreme heat and sea level rise require very different responses. Extreme heat, though more pronounced in Western Sydney, is not primarily location specific. It affects individual health rather than infrastructure and varies according to local issues, such as tree canopy extent, dwelling design and construction, access to resources, and adaptive technologies (e.g., air conditioning). The current adaptation responses for extreme heat in Sydney include urban heat island mitigation, adaptive design, adaptive technology, and community education and communication.

Urban heat island mitigation. Several simple policies and programs can address the causes of the urban heat island and have measurable impacts on lowering temperatures at a local level.

- Increased tree cover. Vegetation is a low-cost natural cooling mechanism that works through both shading and evaporative cooling and offers ancillary benefits to biodiversity, water quality, and recreation. Improved tree cover can be achieved by increasing vegetation in open spaces, streets, and new developments, and by installing green roofs. Tree placement should maximize shade on building walls and roads.
- Subdivision street design. Orientation of streets within a subdivision affects how much they are exposed to sunlight as well as the amount of heat they absorb. In summer streets running east to west essentially receive sun exposure all day, whereas angled alignments maximize shading.
- Light-colored roofs and paving. Surfaces with high albedo and thermal emittance (white and other light colors at the simplest level) reflect, rather than absorb, a greater proportion of energy from sunlight and can reduce temperatures significantly, especially in mid- to high-density developments.
- Minimal energy use. Heat is the end result of all energy used in cities, whether electrical, mechanical, or for lighting or transportation. Directly reducing the use of energy decreases urban heating.

The absence of broad-scale recognition of the urban heat island effect as an issue is the greatest impediment to implementation of mitigation policies. While some planning policies and guidelines in Sydney include urban heat mitigation measures, despite their comparatively low cost, no overall coordination of these efforts has been attempted.

Adaptive design. Building designs that include higher-quality passive solar design and energy efficiency play a significant role in improving both sustainability and interior environmental quality.

In 2000 the NSW government released the Residential Flat Design Code, a set of guidelines that provides benchmarks for better practice in apartment planning and design. Applying this code is intended to help achieve (1) environmental sustainability benefits, including improved energy efficiency and narrow building dimensions to enhance natural ventilation and daylight; (2) improved residential amenities, such as higher ceilings, better layouts, and quality outdoor living spaces; and (3) higher design quality to improve the presentation of the building to the street. While not specifically a climate change initiative, the guidelines and their enforcement through planning codes are part of a significant mechanism for adapting to extreme heat as well as mitigating GHG emissions.

Adaptive technology. While improved building design will assist in lowering indoor temperatures, sometimes significantly, during extreme heat, this benefit will diminish as heat wave duration increases. In many cases air conditioning will be the primary adaptation to reduce indoor temperatures significantly, but the use of energy-hungry air conditioning systems comes at a high financial cost and will have additional impacts as a significant component of increasing total electricity consumption at times of peak loading. While peak electricity demand does not directly impact GHG emissions, it drives investment in new network and power station capacity. Once this investment in additional capacity is made, powerful commercial pressures to maximize returns on this investment take hold and often are accompanied by aggressive selling of energy outside the peak. As a result, in a context of coal-fired electricity generation such as Sydney's, this adaptive response will increase GHG emissions both directly and indirectly, which initiates a climate change feedback loop.

Community education and communication. Community awareness of the risks associated with extreme heat appears to be lacking, even though such events have become increasingly common. Even experienced disaster managers express surprise at the fatality rate attributed to heat waves compared with those for cyclones and floods (Granger and Hayne 2000). Currently, Australia's Bureau of Meteorology does not issue specific heat wave warnings, though at times of extended hot weather advice concerning the dangers of heat stress will be included in normal weather forecasts. The use of more formal heat wave community messaging in Sydney and elsewhere is likely to become more common.

For example, the Central Coast Heatwave Pilot Project, which includes an early warning system and staged media releases, was developed to prepare the area north of Sydney for heat wave conditions that continue for three days or longer. The project ran from September 2007 to the end of March 2008, but that period happened to be a cool and wet summer despite the occurrence of heat waves in other regions of Australia. Thus the heat wave plan was never activated (LGSA 2010).

An alert system to combat heat extremes for Melbourne has been proposed by Neville Nicholls, a professor at Monash University, and the Victorian Department of Human Services. If the average of the predicted maximum temperature on one day and the predicted minimum temperature for the following morning exceeds 30°C, a heat alert would be issued to the public, local authorities, ambulance services, and other health and welfare organizations. The alert would warn of serious health risks and advise simple responses to circumvent heat stress, such as drinking plenty of water, using a fan, wearing light and loose-fitting clothing, and avoiding unnecessary exertion. The alert system could also include responses that would assign increased ambulance and hospital resources during hot conditions and advise citizens to check on elderly relatives or neighbors.

Adaptation Responses to Sea Level Rise

Unlike extreme heat, which affects an individual's health, sea level rise is location specific and has direct consequences for infrastructure. Even though its greatest impact is likely to be on coastal Sydney, with such major economic assets as the financial center, port, and airport located close to sea level, repercussions will be spread over the entire city. Management of disaster responses and emergency recovery has a clear role to play in sea level rise, as do long-term land use policies that include contentious issues, such as planned retreat, where the most susceptible land is abandoned over time in response to increasing risk. The current adaptation responses for sea level rise in Sydney include risk-appropriate land use and emergency and recovery management.

Risk-appropriate land use. Gradually, coastal adaptation practices are being developed and implemented across Australia. They follow a general methodology of protect, redesign, rebuild, elevate, relocate, and retreat (Parliament of the Commonwealth of Australia 2009). If applied consistently over time, these practices will deliver a coordinated response to sea level rise. Byron Shire, in the far northern region of NSW, for example, has a long-established policy of planned retreat for certain beach compartments within its area, but its council has noted difficulties in implementing aspects of it due to a lack of statutory support (Parliament of the Commonwealth of Australia 2009). Work on implementing adaptation for coastal Sydney is not well advanced.

The frequency and severity of storm surge events may have significant influence on how orderly any rebuilding, relocation, or retreat can be. Garnaut (2008, 379) states: "By 2100 under a best-estimate no-mitigation case, measures for coastal protection may not be adequate to withstand the damaging impacts of climate change on buildings. The relocation of industries, activities and households away from certain coastal areas may be the only available adaptation response."

Governments in Australia currently do not provide compensation to the owners or potential developers of land affected by bushfires, coastal hazards, or flood risks, except for some reimbursement and other payments that may be made in relation to an emergency or disaster. Recompense is not provided for any impact on property titles due to erosion or sea level rise. So far, impacts have been gradual, affecting individual landowners rather than entire communities. As more land is affected by rising sea level, however, pressure will mount to see this become a community issue rather than one solely resting with individuals.

Emergency and recovery management. This should be an infrequent and last-stage adaptation. Consistently implemented, risk-appropriate land use policies should manage exposure to storm surges and sea level impacts. In their absence, however, emergency recovery increasingly will become a front line response.

Through various national agencies, the Australian government has comprehensive arrangements in place for disaster and emergency management. The Department of Environment and Climate Change, for example, currently is updating policies to take into account severe weather and storms due to climate change. The NSW government also provides emergency management support during and following major environmental and weather related events, such as bushfires, floods, and major storms. Both state and national governments may provide limited assistance and other payments in response to an emergency or disaster. As the frequency of coastal inundation and damage from storm surges increases, however, and presently rare events become common, it is unclear how the governments may respond in terms of disaster recovery.

Policy Directions for Sydney

Garnaut (2008, 363) warns that "mitigation will come too late to avoid substantial damage from climate change." Despite significant uncertainties, the consensus appears to be that climate change will increase the severity and frequency of existing impacts. Extreme events that earlier might have been expected to happen once in 100 years will occur more frequently. In some cases, such as coastal flooding with a half-meter sea level rise, such events may begin to come about several times during one year (Parliament of the Commonwealth of Australia 2009). Accordingly, management practices and plans will need to be adapted for the changing climate. The framework under which these adaptations occur will need to move toward a probability-based risk management approach rather than remaining rooted in traditional planning approaches based on certainty and presently relevant benchmarks.

Uncertainty about the magnitude of extreme events will result in the management of emergency and recovery services moving into the front line of adaptation. Sydney's emergency response and recovery agencies will require ongoing best practice review and capability development as the nature of extreme weather events due to climate change continues to emerge. A key action is assessment of whether provisions for responding to extreme heat events, storms, and coastal flooding are adequate, given current climate change scenarios. These appraisals require the continual updating of data upon which the risk is assessed and the disclosure of that risk to communities.

Financial and technical resources may enable communities in and around Sydney to assess risk and develop hazard-management plans, such as construction of sea walls, beach nourishment, conservation easements, stormwater retention, and water-sensitive urban design. In general, as the value of the affected land area rises, the likelihood that protective measures will be taken also increases. But significant future costs potentially are associated with protecting assets and ultimately moving entire settlements. An enormous range of approaches to the issue of how such risk-appropriate land use mechanisms should be implemented exists. In particular, it is unclear under what circumstances hard engineering solutions should be preferred to changed land uses and other approaches, and when planned retreat should be required.

An overarching question is, Who will pay for mitigating climate change impacts? Such improvements often involve significant expense for the construction and maintenance of protective infrastructure. Should the benefit flow to individuals and individual property owners rather than to the public? It is unclear at what scale climate change becomes a public rather than a private issue.

Unintended policy consequences will come about as the climate changes. Urban density in Sydney should be increased to reduce the GHG emissions and ecological footprint of the city, but urban heat island effects worsen as density increases. Policies must be integrated across the entire range of mitigation and adaptation issues. In the case of extreme heat, for example, increased density must be accompanied by policies that provide greater tree canopy in dense areas and also incorporate light-colored roofing. This will challenge current systems, particularly where the mitigating action occurs in a separate location from a development, or where incentives are split, such as when tenants' investments lead to landowners' savings, or vice versa.

Often responsibilities for different decision-making events are divided among a number of levels of government and agencies. For planning and design of near-term hazard mitigation activities to be robust, they must consider long-term implications of climate change, which political considerations, budgetary constraints, or simply lack of awareness among decision makers may complicate. The fragmentation of government across metropolitan Sydney is a barrier to coherent and consistent approaches to climate change adaptation.

Australian governments do not have good records for working cooperatively on urban issues. Increasing congestion, decreasing affordability, aging infrastructure, environmental degradation, and a vulnerability to external forces are some of the results. The situation is improving, however, as the following tentative signals indicate.

- The federal government has set up a major cities unit that is more directly engaged with cities and infrastructure and is intended to work toward a national urban policy.
- The NSW government is refocusing on municipal planning and delivery of metropolitan-scale infrastructure in Sydney.
- Through plans such as the City of Sydney Council's Sustainable Sydney 2030, local government is strengthening its links to the community. The residents' vision, voice, and support are fundamental to ensure that change in the form of policies, programs, and projects are appropriate and shared.

Even in instances where governments are motivated to intervene, Garnaut (2008, 363) questions their capacity.

> In many instances, centralised government will lack the agility to orchestrate a differentiated response with the necessary precision to address local needs. The informational requirements of government would be extreme and costly. It is unlikely that an intrusive or directive approach to adaptation would be as effective as one motivated by local interests. . . . The appropriate adaptation response will always depend on a range of local circumstances. Therefore, unlike the mitigation effort, adaptation is best seen as a local, bottom–up response. Households, communities and businesses are best placed to make the decisions that will preserve their livelihoods and help to maintain the things they value.

New Orleans had to undergo the traumatic catastrophe of Hurricane Katrina for these imperatives of cooperation to be recognized. Sydney is not immune from such a calamity. Our challenge is to integrate and cooperate now and avoid the need for a disaster as the catalyzing precursor for change. Whether governments will stand in the way of better governance of our city is yet to be seen.

The following seven conclusions can help Sydney as it moves forward in adapting to climate change.

1. **Continue mitigation**. Sydney should continue with GHG mitigation actions, even as the city is forced to adapt to climate change impacts. While it appears likely that mitigation activities will not prevent the Sydney region

from being exposed to the repercussions of climate change, the city has a strong leadership role to play to mitigate for the most extreme impacts of climate change as part of a global reduction in GHG emissions. Over the longer term, if enacted globally mitigation itself is an adaptive action.

2. **Enhance current adaptations**. Already Sydney is adapting to climate change as it enhances its existing infrastructure, communications, and emergency response systems in order to address gradual increases in extreme weather and related events. An increased focus on reviewing and reassessing those systems will be needed as the ramifications of climate change emerge. The city will also need to prepare for steep changes in the magnitude, frequency, and severity of impacts into the future that go beyond current business as usual.
3. **Densify for sustainability**. Sydney's extremely low density and expanding population—and the large ecological footprint that has resulted—are key issues for the city's sustainability and resilience. Population growth is feasible and may even offer sustainability benefits overall, but not if it comes at low density with concomitant sprawl. Compared to inner and eastern Sydney, the city's urban edge appears to be among the more vulnerable areas to climate change impacts. The social and cultural opportunities offered by a more compact city may also offer enhanced adaptive capacity and resilience to extreme events.
4. **Focus on existing development**. While land use planning plays a key role in adapting to climate change, the city's existing built form will only be adjusted over time. Retrofitting the existing city to adapt to climate change and become far more sustainable in form may not occur naturally or at a pace that accommodates climate change. This enormous challenge includes expensive retrofitting for improved public transport, increased vegetation, and energy efficiency.
5. **Determine who pays.** The question of who should own the various risks of climate change and, as a result, who pays for them poses a difficult policy question. Public and private interests will blur when climate change in key areas is concerned. When economic losses result from climate change that occurs at a large scale, private interests are likely to be portrayed as public ones. Currently public health impacts of extreme heat remain largely private and underreported because they are not geographically colocated or in the public view.
6. **Coordinate governance.** Information and governance structures need to be delivered and integrated in ways that suit the scale of particular climate change impacts. State and national governments are poorly suited to overall sustainability and to delivery of citywide programs that maintain

a nonurban regional focus. At the same time, fragmentation and limited resources for local government result in a lack of a coordinated and cohesive response. The absence of a metropolitan level of governance in Sydney is likely to frustrate urban-scale delivery of climate change adaptation measures. Structures and systems need to be in place to ensure that adaptive processes stay locally focused but are based on coordinated and meaningful regional and national frameworks.

7. **Integrate actions.** An overarching integration of actions, policies, and approaches must be set in place. Ameliorating a single climate change issue must be coordinated across the entire spectrum of activities in order to ensure that other climate impacts are not affected adversely. Long-term mitigation activities have to be integrated to ensure that shorter-term adaptations also are not impeded.

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Figure 8.1 South East Queensland

Source: Weiss and Overpeck, University of Arizona.

dark blue overlay areas = low-lying coastal areas of ≤ one meter elevation vulnerable to future sea-level rise

Chapter 8

South East Queensland

Greg Laves and Peter Waterman

South East Queensland is the fastest-growing regional entity in Australia (figure 8.1). The Australian Government (Allen Consulting Group 2005) and the Intergovernmental Panel on Climate Change (IPCC 2007a) have identified this region as one of the nation's six "hotspots" most at risk from the adverse impacts of climate change. In response to this threat, a range of adaptive responses is emerging, mostly driven from the top down by a variety of policy initiatives from the Australian Government, the Queensland Government, and regional councils. From the bottom up, "climate proofing" has been initiated as an adaptation response through regionally based natural resources management groups and independent community-based actions.

This chapter provides an overview of the regional setting as a spatial framework from which to examine the implications of changing climatic conditions and the emerging adaptive responses. It also indicates the range of governmental responses that are applicable to South East Queensland and offers an example of a growing community-based or bottom-up response to the climate challenge. Overall, it illustrates how adaptive responses can be brought into focus to encompass policy formulation and analysis, strategic and statutory planning, and on-the-ground community actions.

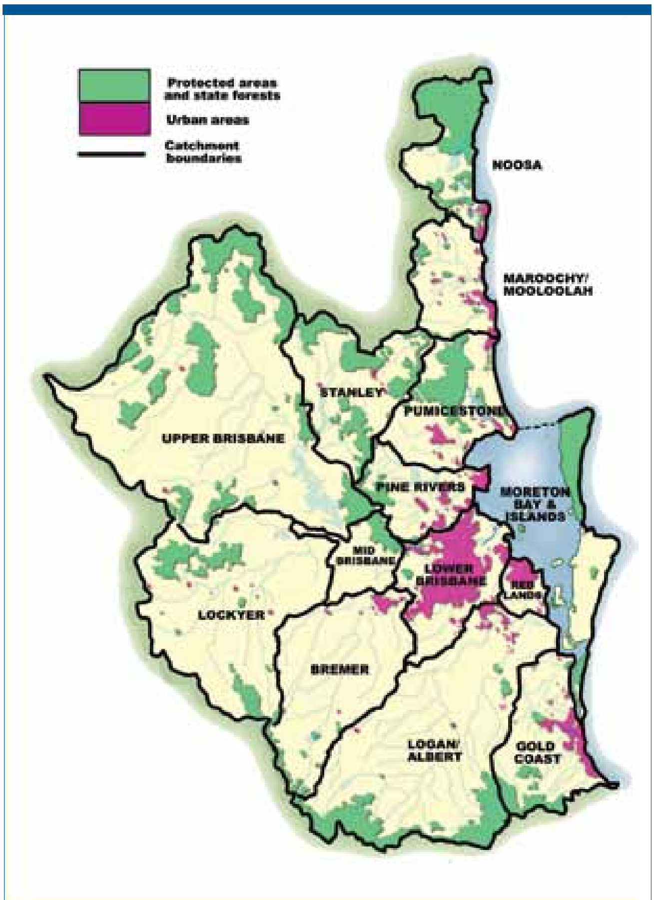
South East Queensland: An Overview

The South East Queensland (SEQ) region encompasses a landscape of changing catchments and coastal regions exposed to the pressures of rapidly increasing populations and associated expansion of settlements and infrastructure that typically accompany them. At the same time, the region is exposed to the hazards and risks arising from climatically induced changes, including more extreme weather, greater climatic variability, and the vulnerability of the region's natural and built environments. These risks are especially significant along its coastal margins, where eroding shorelines and storm-induced flooding have begun to result in significant impacts.

Geography of the Region

The region now known as SEQ was established in the 1830s as a penal settlement administered as part of the colony of New South Wales (NSW).

Figure 8.2 SEQ Catchment Areas
Source: Healthy Waterways (2007) and SEQ Catchments (2010).



Queensland separated from NSW in 1859, and over the past 150 years has become the third-largest state in the Australian Federation. Settlement of the coastal areas preceded expansion into inland areas in search of grazing land for sheep and cattle. In the latter part of the nineteenth century, the discovery of gold, copper, and other minerals coupled with the export trade in timber and processed meat led to the development of distinctive ports as nodes for the inland-rail network. This pattern has been consolidated over the past century as the export of bauxite, aluminum, coal, petroleum products, and nickel added to the economic diversity and strength of the state.

SEQ extends across 14 major river catchments and covers an area of approximately 22,890 square kilometers [km] (figure 8.2). The region stretches from Noosa in the north to the Gold Coast in the south Upper Brisbane and Lockyer in the west. It is the most heavily populated region within the much larger state of Queensland and has the largest concentration of urban development in the state (DIP 2008). In terms of land use, however, built-up and urban areas account for only 2.3 percent of the total land area.

In 2007 the region's population was 2.77 million, and population growth projections from the Department of Infrastructure and Planning (DIP) indicate that it may reach 4.4 million by 2031, when it will account for around 70 percent of the state's population. The current annual growth rate of 2.5 percent is expected to be maintained in the short term and then ease to 1.4 percent by 2031. The major city in the region is Brisbane, the state capital, but extensive development is occurring in the areas known as the Gold Coast and Sunshine Coast. The largest increase in future population is anticipated to be in the two satellite local government areas of Ipswich and Logan (DIP 2008). Among several impediments that may inhibit the continuing population growth are provision of adequate infrastructure, affordable housing, water security, land degradation, and exposure to high-level impacts from climate change.

The SEQ region is made up of ten local government entities, each of which has its own unique character (figure 8.3).

Figure 8.3 **The 10 Local Governments in SEQ**
Source: Laves et al. (2010).

Brisbane: the capital and largest city in Queensland.

Gold Coast City: a major tourist and retirement destination; largest non-capital city in Australia.

Ipswich City: a Brisbane suburb with an industrial and mining heritage.

Lockyer Valley Region: an agricultural area known for its fruit and vegetables.

Logan City: a largely residential area south of Brisbane.

Moreton Bay Region: a largely residential area north of Brisbane.

Redland City: a residential and agricultural area.

Scenic Rim Region: a pastoral area inland from the Gold Coast known for scenic mountains and villages.

Somerset Region: a pastoral area northwest of Brisbane; location of two major dams supplying water to SEQ.

Sunshine Coast Region: a coastal tourist and agricultural region.

The SEQ region contains extensive alluvial valleys, volcanic hills and ranges, and coastal sand masses that support an extensive range of biodiversity. It is renowned for its many unique plants and animals with high conservation significance. A low-lying and narrow coastal plain, sandy beaches, and a series of sand islands along the eastern margin of Moreton Bay characterize the coastal zone. SEQ also hosts a wide range of marine and terrestrial habitats including reefs, rocky shores, mangroves, subtropical rainforest, waterways, lakes, wetlands, and eucalypt forests. Vegetation cover is predominantly of two types, with native forests and woodlands accounting for approximately 45 percent, and annual crops and highly modified pasture making up around 35 percent. Grazing is the dominant land use for nearly 50 percent of the land in the region (BRS 2003).

Apart from the traditional agricultural areas, the region contains a range of sectors devoted to industry, manufacturing, and technology, which include aviation and aerospace, biotechnology, professional and business services, information and communications, mining, and pharmaceuticals. SEQ's natural attractions make tourism an important asset that contributes more than $3.7 billion to the economy and provides employment for more than 61,000 people.* International tourism is particularly significant and is growing at an annual rate of 8 percent.

Regional Temperature and Rainfall Trends

Currently, SEQ experiences a humid, subtropical climate with mild winters and warm summers. December and January are the hottest months, during which daytime temperatures often reach 35°–38ºC. In July, the coldest month, mean temperatures may drop below 10ºC. This amiable climate is a key factor in the rapid growth of both the permanent residential and the seasonal tourist populations. Compared to the baseline established between 1961 and 1990, annual temperature rose 0.2°C to 19.4°C during the period from 1971 to 2000. The 2010 decade shows that temperatures have risen further by 0.4°C to 19.8°C, indicating that the rising temperature trend is not only continuing but accelerating. In addition, mean maximum temperatures are showing a steady increase, rising by 1.0°C over the last decade compared to the 1961–1990 baseline.

Seasonal variations range between a 0.9°C increase in summer and a 1.3°C increase in winter. The number of hot days above 35°C have a northwest gradient, with Brisbane on the southern coast experiencing an average of one day per year, Tewantin on the northern coast averaging three days, and the inland area of Amberley at twelve. While no discernible change has been observed in the coastal areas, the Amberley vicinity has displayed an increasing trend in the annual number of hot days since the 1950s (OCC 2009a).

Rainfall in SEQ is highly variable and influenced by local landform features and vegetation as well as large-scale weather patterns, such as the El Niño–Southern Oscillation. The current mean annual rainfall for the region is 1,135 millimeters (mm) and is characterized by distinct wet and dry seasons. Rainfall tends to be high during summer, when precipitation is delivered by convective storms produced by low pressure troughs moving down from the north. During the winter months rainfall is low and associated with cold fronts moving up from depressions in the south. The northern coastal area of SEQ and the southern border's coastal strip experience annual rainfall in excess of 1,200 mm, while the rest of the region, including Brisbane, may receive annual rainfalls between 650 and 1,200 mm (BOM 2010).

** Unless otherwise noted, dollar amounts cited in this chapter refer to Australian currency.*

Compared to the 1961–1990 baseline period, over the last decade rainfall has shown a marked downward trend of 18 percent, with the most significant decline being in autumn, which has experienced a 32.1 percent decrease. An assessment of whether this trend is associated with climate change is difficult to make, however, due to the high natural variability experienced in the region historically. While the "Millennium Drought"—the longest and driest on record—has dominated the last decade, similar conditions were also recorded during the "Federation Drought" at the beginning of the twentieth century (OCC 2009b).

Extreme weather in January 2011 caused catastrophic floods in SEQ, resulting in loss of lives and livestock as well as considerable damage to property in Toowoomba, the Lockyer Valley, Ipswich, and Brisbane. Following these floods, the management of levels at the Wivenhoe Dam became a major point of controversy. As a consequence, the popular perception that dams can prevent or avert the worst effects of inundation has been drawn into question.

A key point of contention has been whether strategically it is more advisable to conserve water supplies as a hedge against severe drought conditions or to mitigate potential downstream flooding. The operations of SEQ's retention systems, including the adequacy of water releases from the Wivenhoe Dam, are among the issues investigated by the Queensland Floods Commission of Inquiry, which is vested with the powers of a royal commission—the highest form of public inquiry under Australian law. New policy and operational procedures for dealing with extreme weather and climatic variability on storage systems are anticipated as part of the package of this commission's longer-term outcomes.

Climate Change in South East Queensland

Climate Change Projections

The uncertainties embodied in projected climatic conditions for the region present a considerable challenge to those responsible for protecting its people, assets, and environment against such impacts. Among the several indicators that may compel planners in the region to move forward are a discernible trend of increasing temperatures, a drying shift since the 1950s of 50 mm per decade, and the level of global greenhouse gas (GHG) emissions, which as of 2011 is greater than the highest emissions level the IPCC has projected for this time period.

Together, these trends point to a progressively hotter and drier future that may reach the upper ranges of modeled projections. Ultimately, the extent of global warming will depend on the amount of GHG emissions. At the international level, however, advancement on this issue is not progressing at the rate the IPCC has indicated is necessary in order to keep average temperatures at a safe or manageable level globally. It is prudent, therefore, to test adaptation actions with a "no regrets policy" against a model with a degree of risk appropriate to the level of investment.

Areas close to Brisbane's central business district were inundated during flooding in January 2011.
Photograph: © Reuters; Tim Wimbourne.

The shifts in distribution and intensity of regional temperature and rainfall patterns were modeled for the years 2050 and 2100 employing a worst-case scenario that called on the HadGEM GCM climate model developed at the Hadley Climate Centre, an A1FI (high) GHG emissions scenario, and high climate sensitivity. The results compared to the 1961–1990 baseline period are shown in figures 8.4 and 8.5 (Laves et al. 2010). These projections, which are in line with the upper range of those endorsed by the government, indicate the extent of the challenges that the region may face by the end of the century in terms of water security, biodiversity, and human health.

Table 8.1 shows a summary of climate change projections for SEQ from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) that was released by the Queensland Office of Climate Change (OCC 2009a). The potential ranges for key elements indicate that by 2070 climatic conditions may include:

- an increase in mean annual temperatures of up to 4°C, which is above the range of temperatures experienced previously in the region;
- an increase in heat waves and days with temperatures above 35°C (four-fold in the case of Tewantin);
- a decrease in rainfall by up to 30 percent;
- an increase in potential evaporation by as much as 16 percent; and
- an increase in extreme weather events (e.g., storm surges, cyclones, droughts, bushfires).

Figure 8.4 **Mean Annual Temperature Changes in SEQ (°C) by 2030, 2070, and 2100**
Source: Laves et al. (2010).

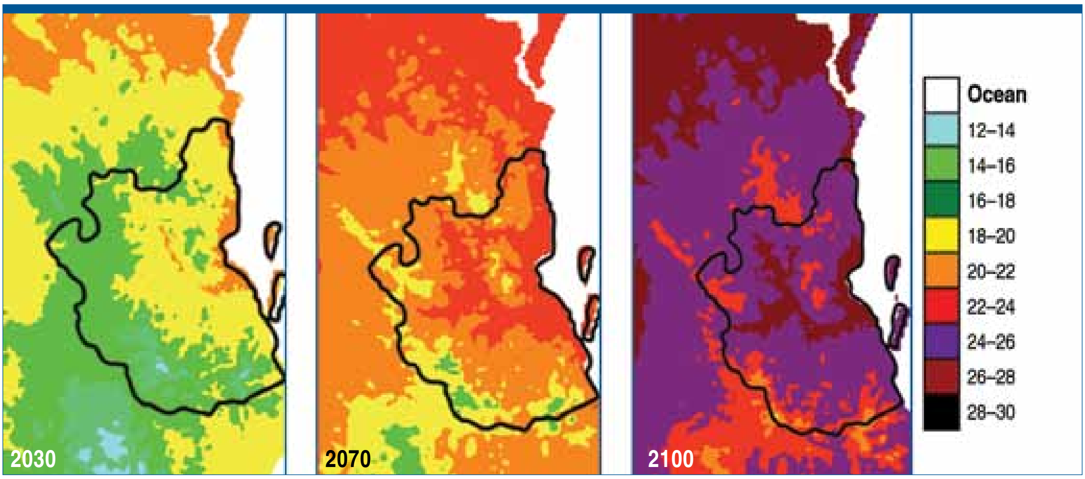


Figure 8.5 **Mean Annual Rainfall Changes in SEQ (mm) by 2030, 2070, and 2100**
Source: Laves et al. (2010).

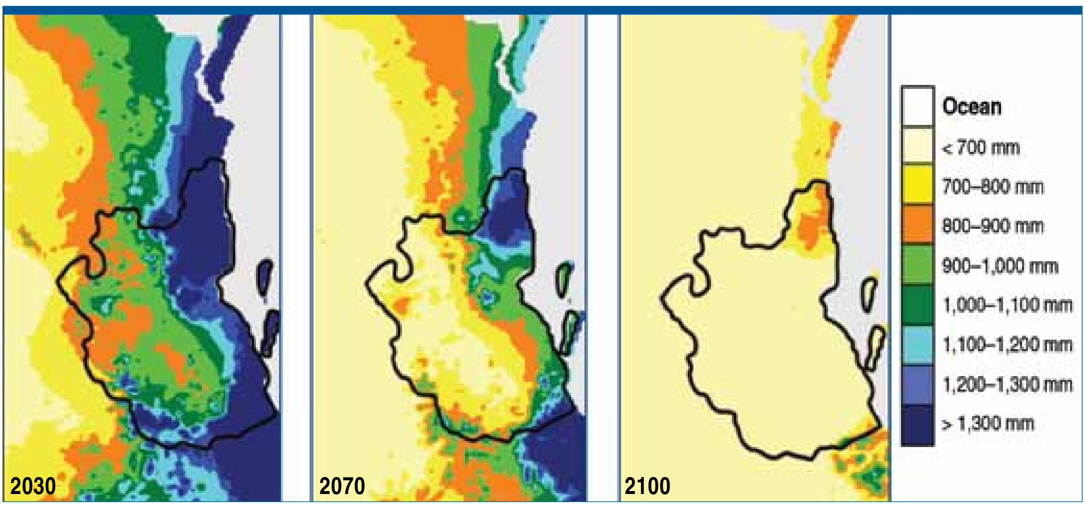


Table 8.1 **Changes to Regional Climate in SEQ**
Source: OCC (2009a).

	Historical Mean	2030	2050	2070
Temperature Increase (°C)	19.4	0.6 to 1.3	0.7 to 2.5	1.0 to 4.0
Rainfall Variation (%)	1135 mm	-11 to +5	-20 to +10	-30 to +17
Potential Evaporation Increase (%)	1553 mm	+2 to +5	+4 to +10	+3 to +16

A number of uncertainties within the scientific and modeling processes used to produce potential climate scenarios make the exact nature of future climatic conditions unclear and have led to much controversy and confusion over how to plan for the best way forward. Such forecasting uncertainties arise from three main sources:

- limited capabilities endemic to global circulation models and the diversity of outputs among various models;
- lack of surety concerning the amount of GHG that eventually will be emitted over any given time period; and
- the global climatic system's sensitivity to increases in atmospheric GHG.

These uncertainties are reflected in the range of potential outcomes for the SEQ region, as illustrated in table 8.1. For example, the variability in mean annual temperatures indicates that the SEQ region may warm between 1°C and 4°C by 2070. Rainfall has an even broader band of uncertainty, both in magnitude and direction. Current best estimates suggest that by 2070 the mean annual regional rainfall may decrease as much as 30 percent, or it may increase by up to 17 percent. The vagueness of these projections frustrates regional planners, policy makers, and other practitioners involved in developing climate change adaptation strategies. The message for climate adaptation workshops and other practitioner forums is very clear: The formulation of adaptive strategies to reduce climate impacts and protect regional assets cannot be driven by the inadequate information now available. Rather, a limited and consistent set of scenarios is needed to identify potential risks that the various sectors should address.

Risks to Water Supply and Security

Rapid population growth and climate change are the key factors that will have negative impacts on the SEQ region's future water security. The projected high population growth will result in a comparable increase in the demand for water in the home, workplace, and recreational environments. The ability to meet this greater demand will be further complicated by the lack of new opportunities to expand harvesting of both surface water and groundwater. Existing climate-dependant water resources are anticipated to diminish due to the reductions in rainfall and increases in evaporation that are indicated by regional climate projections. The water shortages experienced in SEQ since 2005 initiated responses to the longest, most severe drought on record and served to highlight the vulnerability of traditional approaches to water supply. In turn, this has provided a lens to focus attention on the significant challenges facing the planners and resource managers responsible for ensuring long-term water security.

Initially, reaction to the drought was a typical Australian response of imposing restrictions on the use of water outdoors. Up to one-half of household water use is outside the home, so such restrictions traditionally provided a simple, easily policed solution. As the drought continued, and combined dam levels fell to 16 percent of capacity, restrictions became more draconian and had severe impacts on the domestic, commercial, and industrial sectors. Prior to the drought, domestic water consumption was more than 300 liters per person per day (L/p/d). By 2009, Level 6 restrictions—which prohibited the use of water outdoors and limited consumption to 140 L/p/d—had been introduced. At the peak of the drought, in April 2009, household water consumption had dropped to a low of 103 L/p/d (QWC 2009).

Educational programs that encouraged voluntary demand management complemented these mandatory reductions. The programs' primary focus was raising awareness of simple water-saving strategies, such as timing showers, using dual-flush toilets, implementing simple maintenance regimes to reduce losses from leakage, and capturing wastewater from the laundry and shower for reuse in the garden. Financial incentives also were provided to further encourage the transition to low water usage. Evaluation and maintenance services were offered free of charge, and subsidies for the purchase and installation of water-efficient showerheads, toilets, dishwashers, and washing machines were available. It was clear, however, that reducing demand would not be sufficient to ward off the potential disaster of a major city running out of water. Rather, the entire water sector management system required major review and reform.

The need for significant urban water reforms was recognized formally in the 1994 Council of Australian Governments' (COAG) Water Reform Framework, which identified the risks associated with unsustainable water practices. COAG followed this in 2004 with the Australian blueprint for national water reform outlined in the National Water Initiative (NWI). During the drought SEQ adopted many of the NWI's recommendations focused on sourcing and securing climate resilient supplies. Apart from demand management practices, these reforms included providing nonclimate-dependant water sources, such as recycling and desalination; making use of local resources and decentralized approaches, especially in the area of rainwater harvesting; and treating poor quality water so it reaches a level considered "fit for use."

Recognition of the irony of having rain fall over populated areas while catchments that supplied dams remained dry led to the adoption of household rainwater tanks that would provide water for nonpotable uses, such as garden irrigation and toilet flushing. While initially the community was slow to adopt these practices, substantial financial subsidies for the purchase and installation of water tanks and greywater recycling units quickly turned this initiative into one of the region's most successful drought strategies. The recognition that the tanks potentially could supply almost one-third of annual household demand for water led to introduction of legislation making it mandatory for all new freestanding residential dwellings to provide 70 kiloliters per annum of water from local, alternate sources. This regulation is addressed by the inclusion of water tanks in new homes, but the provision of choice has been left open to encourage the development of other decentralized supply options such as recycling.

A plan to upgrade regional-scale centralized systems was also developed during the drought. It included building new dams, although the federal government later ruled out this option on environmental grounds; a regionwide water grid that allows redistribution of water from areas with surplus supplies to those experiencing shortages; the Western Corridor Recycled Water Project, which provides water for industry and power stations; and the construction of a desalination plant on the Gold Coast, with other plants earmarked for construction elsewhere on the coast in the near future.

The drought finally broke early in 2010, and a series of intense summer storms raised dam levels to 97 percent of capacity. Nevertheless, the events of the previous five years left an impression on the collective psyche of the public and the government. Despite the fact that SEQ presently has enough water storage to last several years, a state of permanent water restrictions has been declared with a consumption target of 200 L/p/d. Curiously, however, household consumption has remained below 160 L/p/d, which suggests that consumer attitudes toward conservation may, at least temporarily, have become embedded in daily behavior. The recent events clearly highlighted the potential threat associated with increasingly variable climatic conditions and the need to build climate resilience into the regional water strategy.

Until recent years, SEQ was largely dependent on the capture and storage of surface water. However, investigations into the implications of climate change for water supplied from the region's dams have indicated that its impacts may be dramatic (CSIRO 2006; QWC 2010). The CSIRO (2006, 22) report on climate change risk management states that, in SEQ, "a decline in annual rainfall with higher evaporative rates would lead to a tendency for less run-off into rivers" and consequently into water impoundments, such as dams and weirs. The report also makes the point that "water resources are likely to be further stressed due to climate driven changes in supply for irrigation, cities, industry and environmental flows" (CSIRO 2006, 24).

The SEQ Water Strategy reports that assessments of climate change impacts on the region's dams have identified reductions to dam yields of about 10 percent by 2030 under mid-range emission scenarios (QWC 2009). Specific case studies of particular dams indicate that in some cases reductions of 28 percent of annual inflows may occur, which could result in decreases in yield of approximately 17 percent. The SEQ Water Strategy also states: "Modelling clearly shows that SEQ should be prepared for droughts that are significantly worse than what was experienced during the Millennium Drought" (QWC 2010, 4).

The prospect of expanding the network of dams to meet future demand is poor because "there are few sound opportunities for significant further development of major surface water storages in the region" (QWC 2010, 34). The last potential site for a major dam—at Traveston Crossing—was disallowed by the Australian Government on environmental grounds, thus severely limiting the region's ongoing practice of meeting demand from traditional water sources.

Groundwater resources also are almost fully developed, and in some cases overdeveloped, which accentuates the need to incorporate new strategies that will address the growing problem of water security.

The SEQ Water Strategy outlines a pathway intended to meet demand in the region for the next 50 years (QWC 2010). Among its key elements are:

- reducing per capita water consumption by 24 percent compared to pre-drought trends of more than 300 L/p/d;
- completing a regionwide water grid to allow redistribution from catchments with surplus water to those experiencing shortages;
- developing up to five desalination plants, which will be brought on line and incorporated into the water grid to keep pace with increasing regional demands;
- using more local supplies, such as those from water tanks, storm-water harvesting, and recycling;
- planning for droughts; and
- supplementing water for industry, power generation, and rural irrigation through major recycling schemes including the newly constructed Western Corridor Recycled Water Project.

While strides in regional water reform have been significant, for the most part they have been taken in reaction to an extreme climatic event and are not the result of proactive, reasoned planning. This is typical of the way most climate change adaptation strategies are being developed in Australia—not as part of a unified and coherent climate change framework, but as a series of ad hoc actions, introduced in the guise of sustainability policies, urban water planning principles, or other nonintegrated management instruments. Although these responses are a step in the right direction, developing tactics in isolation can prove maladaptive if they provide benefits to one sector that other areas find problematic. For example, some prefer the solution of building climate-independent desalination plants, in order to establish a guaranteed, continuous water supply, but this approach increases energy use at least threefold over current methods, further contributing to the root cause of global warming. Caution should be taken before committing to a strategy with such a consequence. The opportunity exists to undertake a thorough examination of all emerging options, particularly low-energy, decentralized systems, to ensure that an informed and appropriate strategy is developed.

Sea Level Rise and Coastal Impacts

The IPCC Fourth Assessment Report (IPCC 2007b) indicates that by 2100 global sea level rises are projected to reach between 9 and 88 centimeters (cm). Sources published since the IPCC report, such as Rahmstorf (2007), however, indicate that increases may be as high as 140 cm. The two key processes that generate sea level rise are the thermal expansion of the oceans and melting land ice, and both are driven by the anthropogenic increase of global temperatures. Average sea level rise from 1990 to 2100 has been modeled for the SEQ region using a high (A1FI) emissions scenario (figure 8.6).

Many parts of the coastline are highly developed and include some of the region's most valuable real estate. SEQ also contains extensive stretches of subdivisions with artificial canals created to satisfy the high demand for waterfront properties. For example, the Gold Coast in the southern part of the region has 57 km of coastline, but canal estates have been constructed to provide an additional 800 km of residential waterfront land (Gold Coast City Council 2011). Many of these estates were developed over recent decades with no consideration of the implications of sea level rise or the increased risks from storm surge and coastal erosion.

While inundation from rising sea levels will present a considerable threat to low-lying natural and built environments, the irrevocable retreat of coastlines due to erosion is likely to have a greater impact on near-coast infrastructure, housing, and environmental resources. Shoreline retreat will vary in extent from site to site depending on the local coastal geomorphology. Currently, identification of hotspots is underway through processes such as the National Coastal Vulnerability Assessment and the Queensland Coastal Plan.

The greatest impact of sea level rise will most likely occur during extreme storm conditions, when strong winds and falling barometric pressure create a temporary, localized increase in sea level (MacInnes, O'Grady, and Macadam 2009). Storm surges occurring at higher sea levels allow waves to penetrate further inland, which increases flooding, erosion, and destruction of infrastructure and ecosystems. Using the Bruun rule, a preliminary assessment was conducted on several coastal settlements to arrive at the potential range of coastal erosion implications for sites with different coastal morphologies (Berry and Waterman 2009).

Figure 8.7 shows the extent of possible shoreline retreat for two coastal settlements under mid-range (A1B) and high-range (A1FI) emissions scenarios. While both sites are within tens of kilometers of each other, potential coastal retreat for the two locations varied between 23 and 190 meters for a mid-range scenario and 50 and 389 meters for one based on high emissions. This range of potential threat has highlighted the risk of addressing coastal hazards with a generic policy and the necessity of developing local plans to address local conditions.

Sea level rise implications will be wide ranging and not only will affect those living directly on the coast, but also will have significant economic and social repercussions for coastal communities and the region in general, including the following concerns and outcomes.

- Because more severe storm surges will breach fore-dune areas more frequently and with greater impact, the risk of coastal flooding and storm damage increases with sea level rise ((Berry and Waterman 2009)). In some areas coastal flooding due to storm surges could reach as far as 1 km inland.

Figure 8.6 **Impact of Sea Level Rise on Three Coastal Communitites Along the Sunshine Coast: (A) Caloundra; (B) Mooloolaba; and (C) Noosa**

Source: Laves et al. (2010).

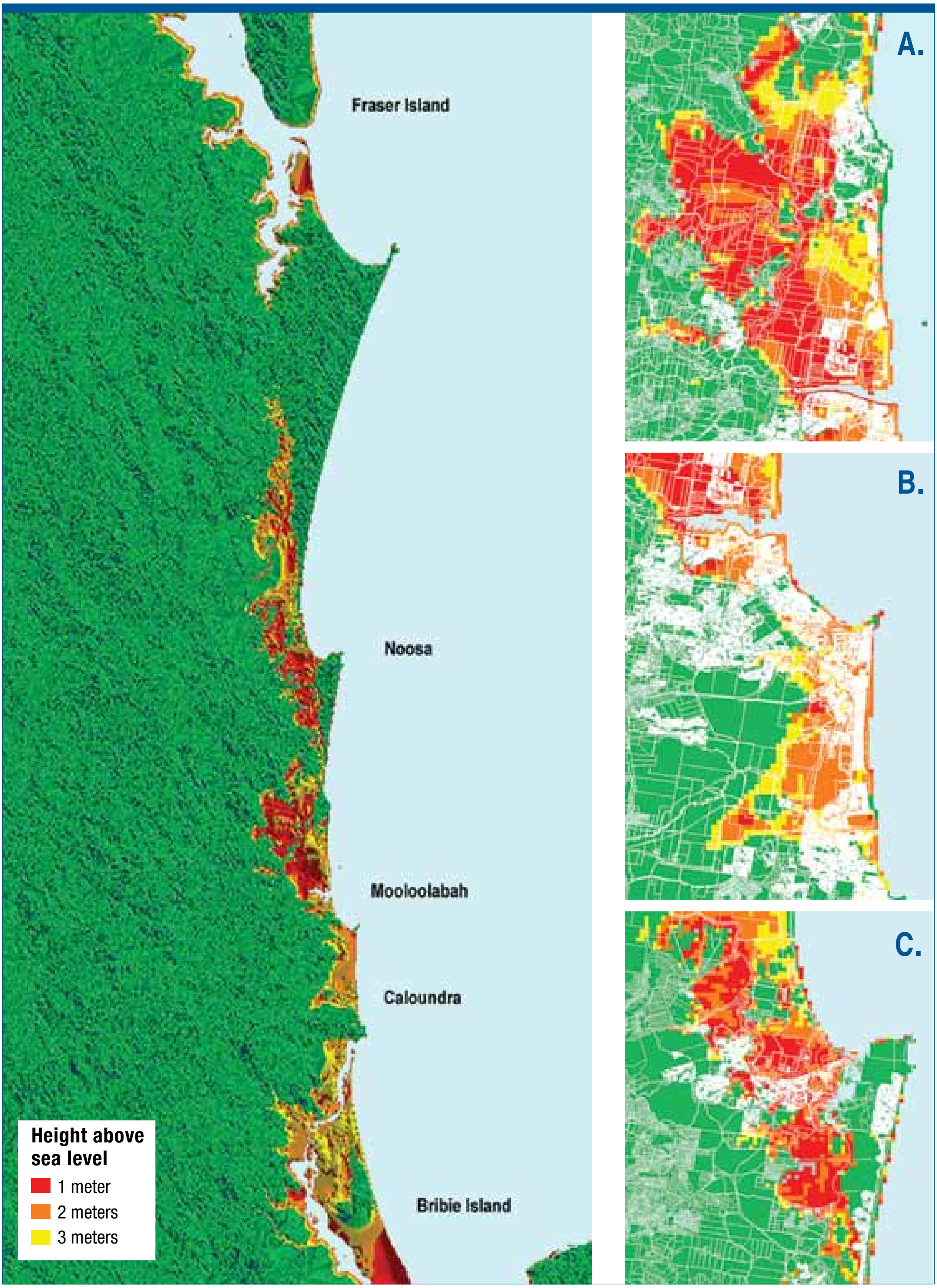


Figure 8.7 Two Mid- and High-Range Coastal Retreat Scenarios, by 2100

Source: Berry and Waterman (2009).

- Losses to coastal biodiversity and ecosystem services will reduce the viability of commercial and recreational fishing, coastal tourism (the mainstay of many coastal towns in the region), and many supporting and service industries.
- The impact on coastal industries, including fishing and tourism, will in turn affect local communities through the loss of employment. Reductions in monies generated by these industries will impact local and state economies in particular.
- Salination of coastal surface water and groundwater will decrease the viability of coastal agriculture that is dependent on irrigation from bores.
- Agricultural land flooded with seawater is more likely to become too salty for continued production.
- Risk of damage and destruction will affect coastal housing and infrastructure.
- The massive cost of coastal protection and relocation, even for small towns, may not be viable in the long term.
- Coastal flooding can increase the risk of water-borne disease and infection.
- The area of liability for coastal erosion and retreat and its ramifications are only begining to be discussed and realized. Who is responsible? Who pays?

In Australian jurisdictions a number of coastal management plans are beginning to emerge, including the Queensland Coastal Plan, which aims to provide policy direction and guidance on managing the state's coastal areas (DERM 2011). This plan recognizes the implications that climate change related issues—sea level rise, coastal erosion, and storm surge hazards, for example—have for continuing development, and it recommends ways to adapt to the rapidly changing, uncertain conditions. The plan also points out the complications that would arise from armoring coastlines to defend existing developments against the natural but undesirable consequences of sea level rise. Such a defensive approach was described as problematic, impractical, and likely to produce negative tradeoffs, such as:

- loss of beaches and intertidal habitat;
- reduced coastal amenities, which impacts local lifestyles and tourism revenues;
- extreme costs;
- transference of erosion problems to adjacent areas; and
- potential risks to property and people.

Rather, the plan's proposed outcomes ensure the protection of people, property, amenity, and the environment, while allowing for natural, physical coastal processes and fluctuations, including those that result from sea level rise. The recommended vehicle for driving these outcomes is adoption of proactive and local planning processes that easily can be suited to local needs and issues. The plan also recommends a set of simple interim guidelines that include:

- incorporating a planning horizon of 100 years;
- assuming a minimum sea level rise of 80 cm by 2100;
- adopting the 100-year-average recurrence interval for extreme events;
- assuming a cyclone intensity at an additional 10 percent over current maximums; and
- providing decadal sea level rise assumptions to guide safety parameters based on the asset life of proposed developments.

Through coastal vulnerability studies and climate change management plans, a proactive process is beginning to emerge in the SEQ region. At present, however, coastal development is proceeding unchecked with little regard for future sea level rise and coastal flooding. Enormous sums of money continue to be invested in urban, residential, and recreation facilities, industrial plants and equipment as well as supporting infrastructure in areas that are likely to be inundated over the next 50 to 100 years. The lack of time to act and the scale of the problem require urgent adaptive action to mitigate the worst of the damage from sea level rise and coastal flooding.

Responding from the Top Down: Regional Realities and Government-Based Adaptive Responses

The impetus and leadership for addressing climate change in Australia as a nation, and in South East Queensland as a region, arose from a top-down approach. At the international level, the United Nations Development Programme and the IPCC have alerted the world to the implications of climate change and initiated global responses such as the Kyoto Protocol. Responding to these concerns, Australia's federal and state governments have acted via the COAG to adopt a range of mitigation and adaptation policies and action plans under the National Climate Change Adaptation Framework (COAG 2007). Following initiatives of various commonwealth, state, and territory governments, regional and local statutory authorities have begun to translate these policies into on-the-ground actions.

Australian Government

Governmentally, Australia shares some commonalities with the United States in that both are federations of states and territories. With respect to land use planning, environmental management, and implementing adaptive responses to climatic change, both countries rest key powers with the states and the territories. Commonly, Australia's national government is referred to as the Commonwealth or the Federal Government. Currently, however, the correct nomenclature is *Australian Government*.

The Australian Government has introduced a broad spectrum of initiatives that address climate change at national, regional, and local scales. Its climate change policy is underpinned by three pillars: mitigation, to reduce Australia's GHG emissions; adaptation, to adapt to the climate change impacts that cannot be avoided; and the global solution, to help shape a collective international response (DCCEE 2010). Queensland is but one of the six states and two territories that constitute the Commonwealth of Australia collectively. Each jurisdiction is addressing the climate change challenge in its own way, albeit within a broad national framework. In their discussion (Byrne et al. 2009), Jason Byrne and his colleagues have examined the national context as well as South East Queensland's situation and urban resilience. They establish a broad comparative benchmark from which to review Queensland's adaptive responses to changing climate conditions.

The National Climate Change Adaptation Framework aims to improve general understanding of foreseeable impacts and strengthen decision makers' capacity to respond concerning major areas of national vulnerability. Among the subprograms that address this goal are the National Climate Change Adaptation Research Facility, CSIRO's Climate Adaptation Flagship, and the Climate Change Adaptation Skills for Professionals Program. Additionally, the Local Adaptation Pathways Program and the Integrated Assessment of Human Settlements subprogram are designed to assist local governments with identifying local climate change challenges and developing their capacity to respond to their impacts.

A number of other Australian government initiatives have strong regional and local implications for SEQ. The intent of the National Coastal Risk Assessments program is to develop an understanding of how climate change may impact coastal settlements. Complementing it, the Caring for Our Coasts policy aims to assist coastal communities in addressing the issues of climate change and rapid population growth. The government's biodiversity vulnerability assessments identify threats facing the nation's rich array of flora and fauna in order to increase understanding of effective adaptation strategies. These assessments are supported by additional investigations of valuable natural assets, including World Heritage properties and the National Reserve System, which includes more than 9,300 protected areas covering nearly 13 percent of the country. Australia's Farming Future, the Community Networks and Capacity Building program, and Water for the Future are among the various related federal policy initiatives.

State Government

Through COAG, the Queensland Government collaborated with the Australian Government and other state governments in 2007 to establish the Working Group on Climate Change and Water and the National Climate Change Adaptation Framework. The Queensland Office of Climate Change (OCC) was also established in 2007 to provide policy and scientific expertise by means of the Queensland Climate Change Centre of Excellence. Shortly thereafter, the OCC produced Australia's first climate action plan, ClimateSmart Adaptation 2007–12, and Queensland's climate change strategy, ClimateSmart 2050. These strategic policies have since been updated with the release in 2009 of the policy document *Climate Q: Toward a Greener Queensland* (OCC 2009b).

The five key action themes that Climate Q addresses are reducing GHG emissions; investing in energy efficiency; investing in technologies for a carbon-constrained world; protecting the state's natural wonders; and adapting to the impacts of climate change. The strategy tackles climate change mitigation and adaptation through a series of initiatives in the areas of energy, planning and building, business, community, primary industry, ecosystems, transport, and government.

Climate Q also recognizes that the potential climatic impacts on the regions will vary and that each region has its own unique set of assets, vulnerabilities, and capacity to develop and implement adaptation strategies. To this end, a series of regional assessments are provided within Climate Q to assist decision makers in the development and prioritization of regional climate change actions and policies (OCC 2009b).

Regional Reponses

Regions can focus attention, give a sense of purpose, and provide a framework for a distinctive set of governmental actions. For example, using catchments as regional boundaries provides a specific spatial context that is relatively easy to delineate and understand (see figure 8.2). SEQ was identified in the Climate Q strategy as having the potential to face major challenges as a result of climate change. Its coastal settlements are at additional risk from sea level rise, coastal development, and rapid population growth. To respond to these and other regional challenges, a number of policy and planning instruments, sustainability programs, and a climate change management plan have been embodied in or implemented through the SEQ Regional Plan.

The first policy instrument is the three-year South East Queensland Climate Adaptation Research Initiative (SEQCARI), which aims to determine the region's vulnerability to climate change and identify appropriate adaptation strategies for the government, industry, and communities (DIP 2009b). While research and government partners fund the initiative, the process is guided by an advisory panel of regional stakeholders. Research outcomes from SEQCARI will be used to inform the actions of the second major policy instrument, the South East Queensland Climate Change Management Plan (SEQCCMP 2009).

Structurally, the SEQCCMP is a component of the SEQ Regional Plan 2009–2031, a statutory and preeminent planning scheme that determines regional outcomes, principles, and policies in relation to a broad range of planning issues (DIP 2009a). The incorporation of the SEQCCMP into the regional plan ensures that adaptation and mitigation doctrines are embedded within the planning process and that future development needs will be balanced with climate-resilient and sustainable best practices.

The SEQ Regional Plan emphasizes the need for sustainable growth and the importance of addressing climate change. Adaptation principles focus on the need to increase resilience to natural hazards in communities, infrastructures, the environment, and the economic sector. To achieve this, proposed policies and programs aim to reduce risks from natural hazards, implement planning schemes and development decisions, align and coordinate implementation of regional policies in order to increase resilience, and develop planning and design performance criteria for development and infrastructure. The plan also recognizes that, to be successful, the elements of the regional hierarchy—the region overall, local government authorities (LGAs), neighborhoods, buildings, individuals, and communities of space and interest—must embrace its principles. This approach is defined clearly in a set of climate change aspirations (DIP 2009a).

Local Government

Three key factors need to be taken into account when considering how Australia's LGAs can play a role in adapting to changing climatic conditions. First, since the local sphere of government does not have constitutional recognition, LGAs comprise an arm of the state. As such, local government operates under specific state or territorial legislation (including a Local Government Act), and the Australian Capital Territory (ACT) entails no local government. As benchmarked by the Advisory Council for Inter-Governmental Relations (ACIR 1986), wide differences in roles and responsibilities exist among local governments in each state and the Northern Territory.

The second factor arises from the fact that Australia's population is concentrated in coastal metropolitan regions, making the country one of the most metrocentric in the world. Some 85 percent of the population lives in the capital cities and within 50 km of the coastline (Beeton et al. 2006). Nationally, LGAs are separated by enormous geographic and demographic differences, including the spatial extent accommodated by individual local councils; the patterns of settlement encompassed within council boundaries; and the size, density, and distribution of the various populations.

The last of the three key factors reflects the widely differing levels of awareness that elected members and staff of local councils have concerning their specific LGAs' inherent vulnerabilities to the climate challenge. In turn, the capacity and capability of individual councils to respond in the context of their geographic and demographic realities is affected.

Three additional factors set local governments in Queensland apart from their counterparts in other Australian jurisdictions. First, its LGAs are delineated on a regional basis and encompass quite large populations. All elected members in Queensland are employed full-time in the position of councilor, whereas in New South Wales only mayors of the larger cities and coastal LGAs are employed full-time. In other jurisdictions, councilors usually are part-time employees and receive allowances or sitting fees, although they may also have other forms of employment. Thus, councilors in Queensland can become more involved in addressing day-to-day problems as well as strategic issues, such as responding to changing climatic conditions, than their counterparts in other states can. This also means that Queensland's LGAs may be viewed as having a greater capacity to respond to current and emerging issues using climate change policy and statutory planning instruments.

Second, the climate change policy setting in Queensland is better developed than it is in other jurisdictions, which endows its councilors with greater strategic guidance. Climate change concerns are embedded within the key statutory planning instruments for the SEQ region, and these plans are complemented by specific responses, as illustrated by the SEQCCMP (2009). Specifically, the regionally delineated coastal councils have major responsibility for developing and implementing statutory land use planning instruments. These cover settlement patterns and demographic pressures; provision of regional and local infrastructure; emerging issues, such as climate change adaptation and mitigation at the regional and local scales; short-term impacts such as extreme weather events leading to flooding, drought, and bushfires; and long-term issues including the sustainability of water supplies, loss of regional biodiversity, and rising sea levels. In short, elected members and officers of the regionally delineated LGAs already hold the key tools and roles needed to plan for climate change.

Third, a number of LGAs in Queensland have developed their own regionally based responses as illustrated by the Gold Coast City Council, Morton Bay Regional Council, and Sunshine Coast Regional Council (SCRC). Brisbane's city council is also responding to the climate challenge through planning policy and sustainability initiatives. Various policy instruments have been prepared using expert input from consultants and, in the case of the SCRC, an officer of the council whose postgraduate qualifications are specifically in climate change adaptation. Broad community response was sought during preparation of the various documents. Collectively, the strategies and action pathways have been well received by the respective communities of space, interest, and spirit.

The Way Forward from the Bottom Up: Climate Proofing Regions and Communities

Peter Waterman (2009) and his colleagues (Waterman et al. 2009) make the point that climate proofing is a bottom-up approach to adaptation that has been adopted by international bodies such as the Asian Development Bank (ADB 2006), the World Bank (2006; 2008a; and 2008b), and several European organizations. Climate proofing describes the suite of actions needed to make areas and assets resistant to climate variability and change and to make communities and people more resilient (Hay et al. 2004). As such, it can be a useful strategy to help regions and communities focus on mainstreaming climate change adaptation into planning and development actions. Advocates also argue that such adaptive responses are needed at multiple scales. It follows that climate proofing activities at the regional, local, and community levels can assist in preparing SEQ governments and civil society to meet the climate challenge (White 2006).

Natural resource management groups, such as South East Queensland Catchments (SEQC) and the Burnett Mary Regional Group (BMRG) in collaboration with the Climate Change, Coasts, and Catchments program at the University of the Sunshine Coast have promoted climate proofing in SEQ. This initiative is coordinated through the SEQ Climate Proofing Demonstration Project, which began as a practical response to the governments' and communities' growing concerns over the vulnerability of coastal regions to the projected impacts of changes in climate and the environment. In particular, the project is responding to a key question—What can we do to adapt to climate change?—that stakeholders from across industry sectors, communities of space and interest, and members of the public are asking.

The project's approach has three components: (1) fostering integrated approaches to climate change adaptation through risk reduction; (2) identifying and developing tools and techniques for integrated vulnerability assessment and management that address regional, local, and site-specific environmental conditions; and (3) initiating and supporting community awareness and capacity building to equip local and regional stakeholders to deal with current climatic variability and projected climate change and sea level rise.

Angie White and Peter Waterman (Waterman 2009; White 2006; White and Waterman 2006) make the case that, together with the accompanying integrated environmental management, vulnerability and adaptation assessment can be tailored to the geographic realities of specific regions and localities, including community capacities. In other words, they can be applied to form a regional development strategy. The approach is shown schematically in figure 8.8, the chronology of work undertaken is summarized in table 8.2, and the achievements to date are shown in table 8.3.

A case has been developed to illustrate how the project work in SEQ to date could be built on and rolled out by regional bodies, LGAs, and communities as a long-term regional development strategy. The bottom-up approach demonstrated in SEQ has been implemented at very low cost and has received great community support. It is easy to adopt because it builds on the organizational and governance strengths inherent in regional communities and the personal and professional skills and experience offered within civil society.

Figure 8.8 A Staged Approach for Climate Proofing Coastal Regions and Communities in SEQ

Source: Waterman (2009, 10).

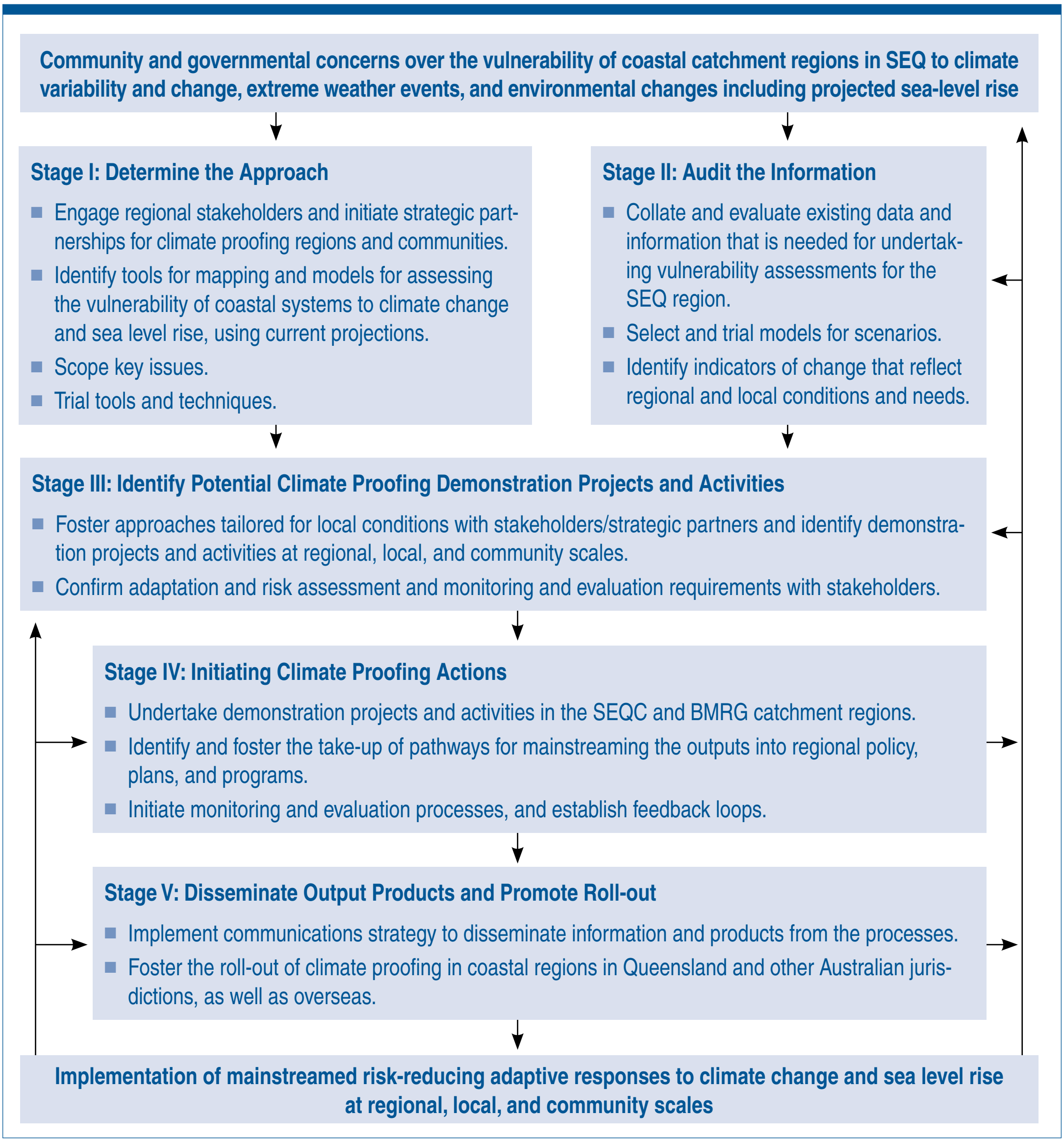


Table 8.2 Chronology of Climate Proofing Work Undertaken Through SEGRA, SEQC, BMRG, and Shell Australia–CVA Initiative, 2005–2009

Source: Waterman et al. (2009, 12).

Year	Workshop and Forum Activities	SEQ Catchments (SEQC)	Burnett Mary Regional Group (BMRG)
2005	SEGRA* climate proofing (CP) workshop: Yepoon	Phase I: Awareness and capacity-building workshops	
2006	SEGRA CP workshop: Launceston	Phase I: Awareness and capacity-building workshops; applied research on regional climate change scenarios	
2007	SEGRA CP workshop: Wollongong	Phase II, Part 1: Community climate proofing activities on Coochiemudlo Bribie Island Phase II, Part 2: Climate change and ecosystem-services mapping project	Scenarios building and planning project, encompassing: • regional climate change scenarios; • coastal vulnerability; • settlements, and infrastructure • water security; and • farm and plantation forestry sectors
2008	SEGRA CP workshop: Albury	Phase II, Part 3: Climate proofing biodiversity corridors	Regional CP workshops
2009–2011	SEGRA CP workshops: Kalgoorlie-Boulder, Townsville, and Geelong Shell Australia and Conservation Volunteers Australia Climate Change Forums: Gladstone, Sunshine Coast, Toowoomba, Adelaide, Broome, Newcastle, Wollongong, Mackay, Cairns, Geelong, Ballarat, Launceston, Bathurst and Darwin	World Environment Day Festival for the Sunshine Coast Region at the University of the Sunshine Coast Finalize climate proofing biodiversity corridors and continue "Coochie and Bribie" activities Roll-out of promotion of climate proofing through conference presentations and community-based awareness-raising activities	Finalize working papers, scoping reports, and "planning for climate change" awareness-raising materials for the Burnett Mary region as source information for regional local government authorities and community-based organizations. Information dissemination and evaluation

**Sustainable Economic Growth for Regional Australia (SEGRA) Conference*

Table 8.3 Overview of Work Undertaken for SEQ Climate Proofing Demonstration Project

Source: Waterman et al. (2009, 12–13).

Stage	Actions, Activities, and Outcomes	Products and Comments
I	Project conceptualization: • Strategic partners frame and agree on multiple approaches • Initial stakeholder engagement meetings held with community organizations and local governments in SEQ and Burnett Mary regions Phase I climate proofing initiated by SEQC: • Successful awareness raising, issues scoping, and capacity-building workshops held in SEQ region by SEQC and Climate Change, Coasts, and Catchments program at University of the Sunshine Coast	• Concept flyers promoting climate proofing • Conference presentations and papers • Capacity building with hands-on use of climate-modeling software, such as SimCLIM • USC professional development programs in climate change adaptation and Integrated coastal zone management
II	• Audit regional and local scale digital elevation models (DEM) and meteorological data • Identify key information requirements for vulnerability assessments and climate proofing activities	• Honors thesis on model selection and information auditing • SimCLIM trials at regional scale
III	Confirm approaches with stakeholders Phase II climate proofing initiated by SEQC; includes • climate proofing Coochiemudlo and Bribie Islands The Building Local Government Resilience through Scenario Planning Project initiated by the BMRG focuses on climate change implications for: • Coastal vulnerability; • Water security; • Residential, tourism, and recreational pressures on infrastructure; and • Plantation and farm forestry	Reports to SEQC on mapping climate change dimensions of ecosystem services and biodiversity corridors SimCLIM applied to regional climatic conditions in areas covered by SEQC and BMRG regional scenarios Scoping reports and working papers for scenario themes for BMRG
IV	• Climate proofing meetings and workshops on Coochiemudlo and Bribie Islands • Community groups on islands set priorities for actions to suit local conditions and needs • BMRG state and local government stakeholder-focused workshops for coastal and catchment LGAs	Initial set of climate change projections for the SEQ-BMRG region • Observed climate change over the last 60 years is consistent with global predictions • Trends are indicative of expected future changes
V	• Workshops on climate proofing regions as part of annual SEGRA conferences • Initiation of interstate activities (e.g., Goldfields-Esperance Development Commission and Conservation Volunteers Australia)	• Dissemination of SEQC and BMRG working papers and scoping reports • Conference papers and public presentation

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Figure 9.1 **Perth**

Source: Weiss and Overpeck, University of Arizona.

dark blue overlay areas = low-lying coastal areas of ≤ one meter elevation vulnerable to future sea-level rise

Chapter 9

Perth

Laura Stocker, Peter Newman, and James Duggie

Perth is a rapidly growing, modern city of 1.6 million people in the southwestern corner of Australia—more than 2,000 kilometers (km) from the nearest Australian city and 12 time zones from the East Coast of the United States (figure 9.1). The adjacent Indian Ocean provides a powerful sense of place for many Western Australians. A favorite local novelist, Tim Winton (1993, 3), has commented: "There is nowhere else I'd rather be than here, nothing else I would prefer to be doing. I am at the beach looking west with the continent behind me as the sun tracks down to the sea. I have my bearings."

The Indian Ocean and the west coast of the Australian continent are beginning to change climatically, however, and as a consequence so will the residents' lifestyles. Perth has been identified as a miner's canary for climate change (Sadler 2004). Early modeling in a global assessment of greenhouse issues suggested that this corner of Australia would suffer rainfall decline, and indeed it has (Pittock 1988). After recording a 50 percent decline in rainfall run-off, in the late 1990s the Water Corporation, which manages water services in Western Australia, changed its policy in recognition that this decline was due not to drought but to climate change.

Neither the global community nor Australia has been able to find an adequate, large-scale, internationally accepted solution to climate change, but many smaller solutions are well underway and need to be expanded. In this chapter we describe some examples of practices in Perth and its bioregion that offer lessons in understanding the science, learning to adapt, and beginning to mitigate the effects of climate change.

Perth: The Place and the Problem

Perth is the capital of Western Australia, the state that occupies the western third of the continent and occupies a land area of about 2,529,880 square kilometers (km^2) (ABS 2011a). It is the most isolated capital city in the world. The state's population of 2,236,900 comprises 10 percent of the country's total population, but most of the state is sparsely populated, with almost three-quarters of its residents living in metropolitan Perth (ABS 2011b). Both the state's population and its economy have been growing rapidly in recent decades, and these trends are projected to continue over the next 20 years or more. Perth is the administrative and commercial center for much of the economic activity of the state, including the mineral and natural gas resources industries, which together make a significant contribution to the economic growth and wealth of the state and Australia as a whole. Western Australia also has a very productive agricultural industry and attracts a growing number of tourists.

Perth is located on the Swan Coastal Plain and centers on the Swan River and its estuary (figure 9.2). The plain is roughly 100 km wide, running far to the north and south of the city, and is bounded to the east by the Darling Scarp. The city has developed in a low-density, radial settlement pattern that has been modified by the parallel boundary constraints of the coast to the west and Darling Scarp to the east as well as by the region's groundwater resources. Although a small number of urban and peri-urban settlements occur east of the Darling Scarp, it generally acts as a natural boundary beyond which native forests managed by the state government dominate a rolling landscape. This region is dissected by the catchments for 13 relatively small-scale public water supply dams. Further east beyond the forests is an extensive and largely cleared agricultural landscape in the southwestern corner of the state, which receives high- to medium-rainfall levels.

The temperate Mediterranean climate brings hot, relatively dry summers, and colder, comparatively wet winters. Mean maximum temperatures are 30.8°C in January and 18.3°C in July; mean annual rainfall is 751 millimeters (mm) (ABS 2011b). This chapter examines observed and projected climate change impacts for Perth, surveys some of its greenhouse gas (GHG) mitigation responses, and describes some adaptation responses, such as adjusting public water supplies to take into account declining water availability and dealing with coastal management and local government issues.

Impacts of Climate Change

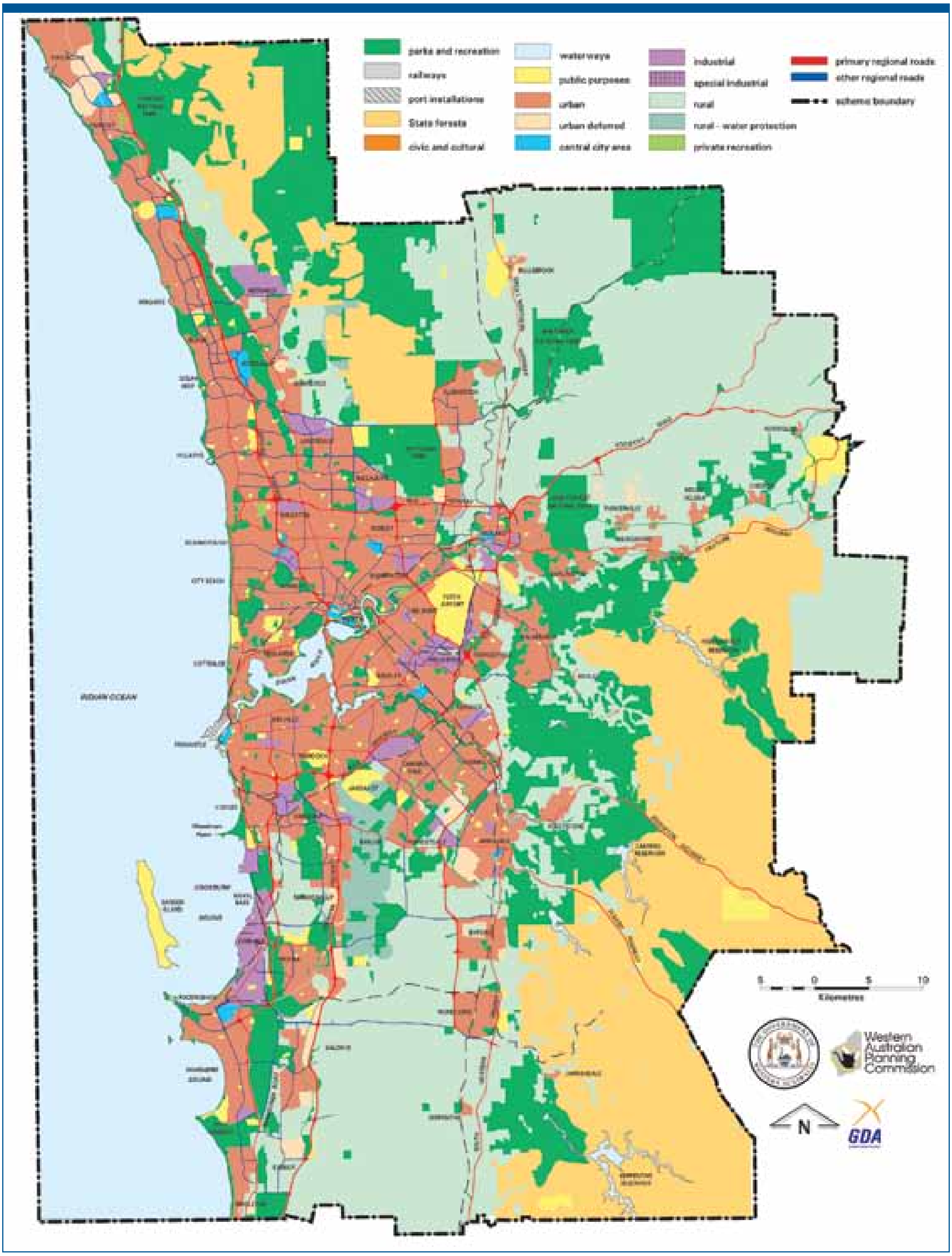
Rising temperatures in the atmosphere and sea are affecting atmospheric circulation as it approaches the state, and in turn these changing patterns have had an impact on rainfall and increased risks of extreme climatic events.

Temperature Rise

Average temperatures in Western Australia increased by 0.8°C between 1910 and 2005, with most of the increase occurring after 1950. The trend in mean temperature has varied within the state, and Perth is among the areas that have experienced the highest levels of warming (Cramb 2005). From 1910 to 2009 the trend in mean temperature for Perth was a warming of 0.15°C every 10 years, and from 1970 to 2009 it increased to 0.20°C every 10 years (BOM 2010a). Winter and spring had the greatest levels of warming, and summer the lowest (Cramb 2005). Over the last 40 years Perth has also experienced a slow increase in the number of very hot days (above 35°C).

Figure 9.2 Perth Metropolitan Region Scheme Zones

Source: Western Australian Planning Commission (2011)).



This map indicates the location of urban zoned land as well as transport corridors, including rail lines; state forests and other native vegetation; and protected water supply catchments and groundwater sources.

http://www.planning.wa.gov.au/5386.asp

The summer of 2009–2010 was the hottest and driest on record. Throughout that season, from December 2009 to February 2010, Perth recorded just 0.2 mm of rain, whereas the long-term average is 32 mm during the same period. Perth also experienced a total of 59 days at or above 30ºC, also a new record (*WA Today* 2010). The average number of days per year with temperatures greater than 35ºC is projected to increase from 28 (between 1970 and 2000) to between 30 and 43 days in 2040 (Suppiah et al. 2007). Projections for Perth's mean temperature suggest it could increase by between 0.6°C and 1.5ºC by 2030 (figure 9.3).

Sea Temperature Rise

To the west, Western Australia is bordered by the Indian Ocean, which has a major influence on the atmospheric circulation patterns affecting the state and thus on the regional climate that they bring. The sea surface temperatures of the Indian Ocean vary over its spatial extent and over various time scales, but they have been warming over the last 50 years. For the decade from 1991 to 2000, the average sea surface temperature over the entire basin increased by 0.6ºC above the baseline established during the 1900–1960 period, and since 2000 it has continued to warm (Feng, Meyers, and Church 2005). One of the areas of greatest increase in surface temperature is the coastal area around Perth, where it is projected to continue this rise (Caputi et al. 2009; figure 9.4).

The Leeuwin Current, a boundary ocean current that flows southward along the coast, dominates the Perth region's coastal environment. The current's strength varies as a function of several factors, including the occurrence and intensity of La Niña and El Niño climate patterns. A decline in its strength was observed between 1950 and the 1990s, and climate scientists think it is possible that climate change may further weaken the Leeuwin Current, which will have many ecological and economic implications for both the Western Australian marine environment and the continuing decline in rainfall (Feng, Meyers, and Church 2009).

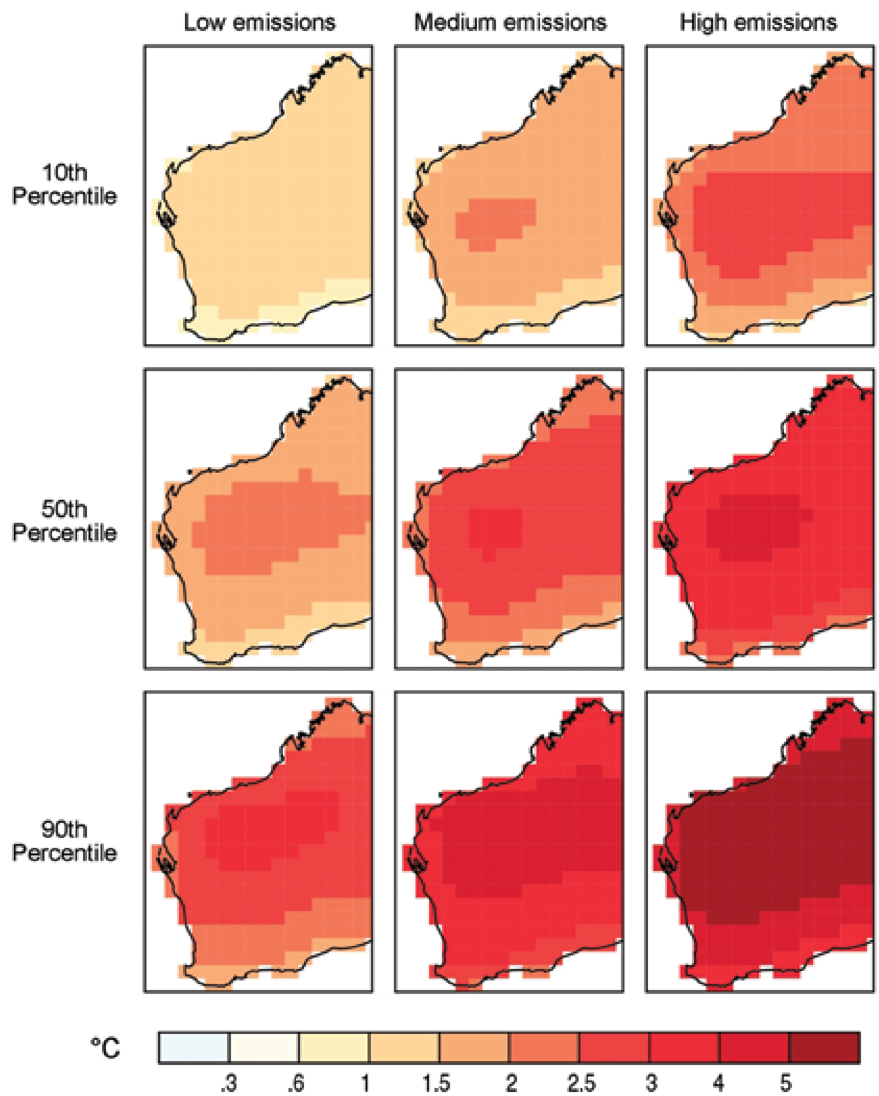
In particular, "any seasonal variation in water temperature increase has important implications for fisheries and the marine ecosystem because it may affect many aspects of the annual life cycle such as timing of growth, moulting, mating, spawning and recruitment," which have to be taken into account in the stock assessment and management of fisheries (Caputi et al. 2009, 130). For example, in the last few years the western rock lobster fishery has experienced a dramatic decline in numbers at an important early life cycle stage of this economically valuable species.

In February 2011, Western Australia experienced a marine heat wave. Over a large area extending from Ningaloo to the Abrolhos and more than 200 km offshore, surface temperatures were more than 3°C above average for the time of year. In an area that reached from Exmouth to Cape Naturaliste and

500 km offshore, the average temperature was more than 2°C warmer. This heat wave was associated with a number of fish kills along the midwest coast and in the Abrolhos, Kalbarri, and Leeman areas. Rock lobster and abalone deaths also were reported in areas of very warm and calm water (Department of Fisheries 2011).

Figure 9.3 Projected Summer Temperature Increases (°C) for Western Australia in 2070

Source: BOM and CSIRO (2010b).



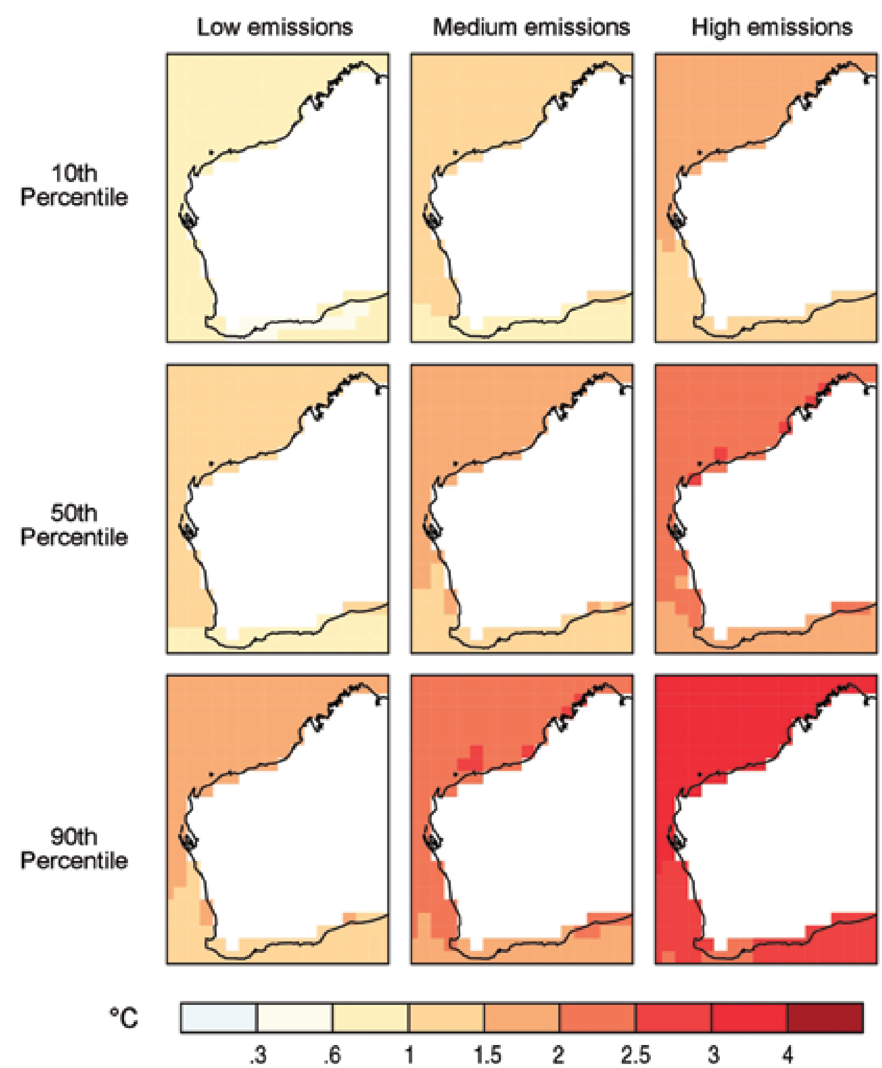
Projections, cited relative to the 1980–1999 period, give an estimate of the average climate around 2070. The 50th percentile (midpoint of the spread of model results) provides a best-estimate result; the 10th and 90th percentiles (lowest and highest 10 percent of the spread of model results) indicate a range of uncertainty. Emissions scenarios are taken from the IPCC Special Report on Emission Scenarios: The B1 scenario accommodates low emissions, A1B is medium, and high is A1FI.

Sea Level Rise

Perth's port activity takes place in the Fremantle area, which has recorded one of the longest time series of sea level data in the Southern Hemisphere (figure 9.5). Mean sea level rise at Fremantle has increased by nearly 20 cen-

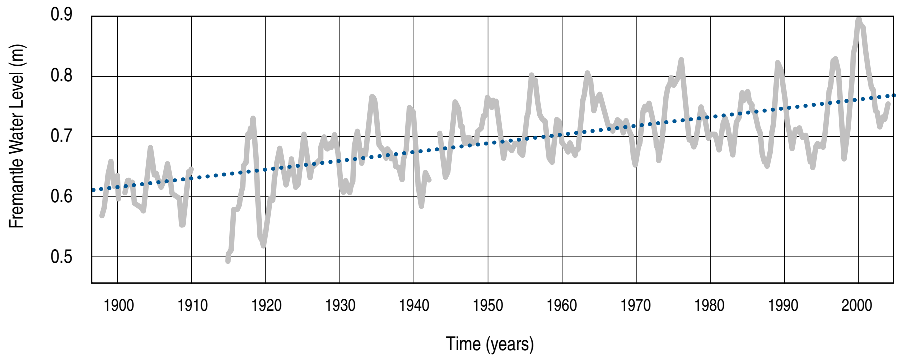
Figure 9.4 Projections for Sea Surface Temperature Change (°C) for Western Australian in 2070

Source: BOM and CSIRO (2010c).



Projections, cited relative to the 1980–1999 period, give an estimate of the average climate around 2070, but individual years will show variations from this average. The 50th percentile (midpoint of the spread of model results) provides a best-estimate result; the 10th and 90th percentiles (lowest and highest 10 percent of the spread of model results) indicate a range of uncertainty. Emissions scenarios are taken from the IPCC Special Report on Emission Scenarios: The B1 scenario accommodates low emissions, A1B is medium, and high is A1FI.

Figure 9.5 Mean Sea Level Rise at Fremantle, 1900–2000
Source: Pattiaratchi and Eliot (2005).



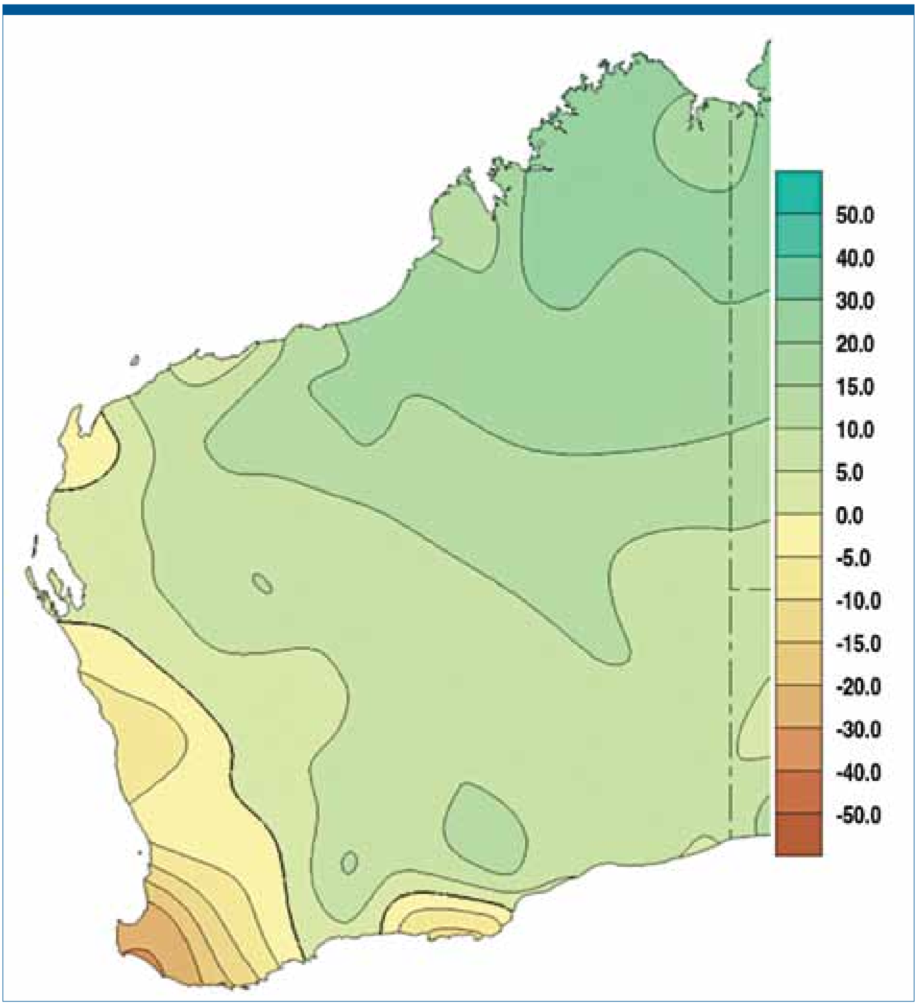
timeters (cm) since 1897, representing an average rate of increase of 1.54 mm per year, which is equivalent to 20 percent of the maximum tidal range for the port (Pattiaratchi and Eliot 2005). This average increase is consistent with the 1.7 mm per year global average sea level rise, which is also increasing; between 1993 and 2009 it rose by 3 mm per year (BOM and CSIRO 2010a). Although these might appear to be relatively small increases, they can result in greater return frequencies for storm surge and other temporary high sea level rise events.

Further complicating the trends in sea level rise is the interannual variability driven by the El Niño–Southern Oscillation (EN–SO), which is superimposed on the sea level data. Sometimes the EN–SO slows the rate of observed sea level rise over a period of years, and at others it temporarily accelerates it. The latter reinforcing effect, along with the long-term sea level rise, has contributed to the apparent increased frequency of coastal flooding in the period from 1995 until 2004 (Eliot 2009), and the historic maximum sea levels recorded in Fremantle in 2003 and 2004 (Pattiaratchi and Eliot 2008). The increased frequency of flooding events has helped raise public awareness of coastal hazards. In terms of future sea level rise in the Perth region, “the predicted increase is up to 0.30 m and 0.88 m by 2040 and 2100, respectively. For sandy beaches this could result in beach recession of 30 m by 2040” (Pattiaratchi and Eliot 2005).

Rainfall Loss

The Perth region has experienced a 20 percent decrease from its long-term average rainfall (figure 9.6). Any reduction in rainfall causes an even greater reduction in stream flows into areas that are rain dependent, as illustrated by up to 50 percent reductions in stream inflow into the public water supply dams for the region (figure 9.7). The annual inflow into the Perth dams has declined from an average of 338 gigaliters (gL), between 1911 and 1974, to 177 gL between

Figure 9.6 Trends in Total Rainfall for Western Australia, 1910–2009 (mm per 10 years)
Source: BOM (2010b).

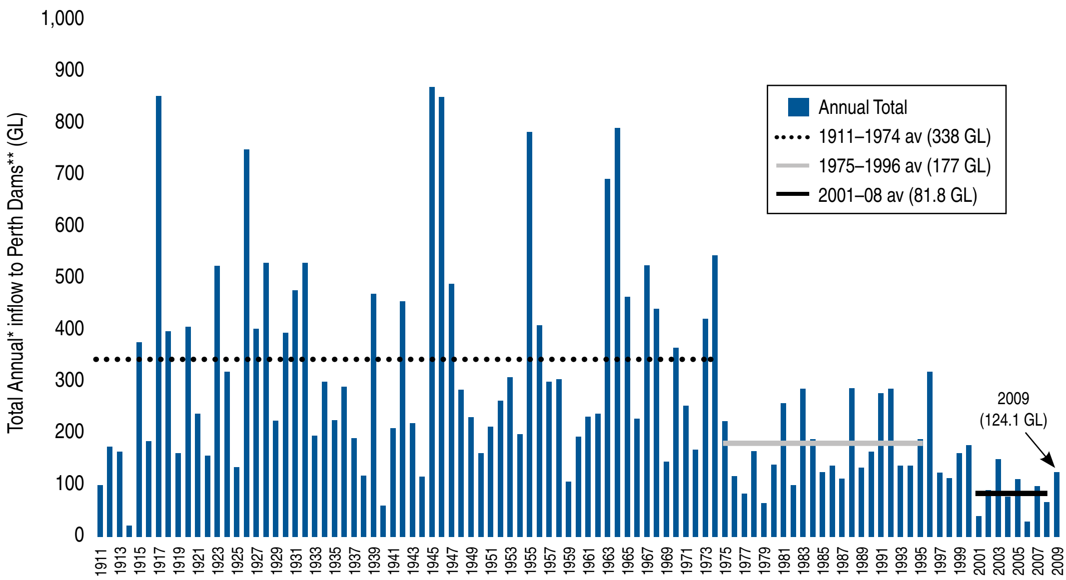


1975 and 1996, and it dropped again to an average of just 81.8 gL between 1996 and 2008 (Water Corporation 2009a). The average inflow over the last decade has been 75 percent less than the pre-1970s average. This dramatic reduction in inflow into the dams has resulted in a consequent loss in their capacity to supply water for the public water system.

Climate change projections for future rainfall in Perth suggest that annual total rainfall could decrease by as much as 20 percent by 2030, with mid-estimates being 5 to 10 percent (Suppiah et al. 2007). Figure 9.8 shows projections for rainfall change to 2070. Its already limited rainfall has led Perth to begin to access extensive groundwater supplies in the sandy shallow aquifer to the east of the city, and more recently to develop a greater reliance on desalination plants.

Figure 9.7 Annual Inflow into Perth Dams

Source: Water Corporation (2009a).



** Year runs from 1 May to 30 April. ** 2009/10 inflow to 21 October 2009.*

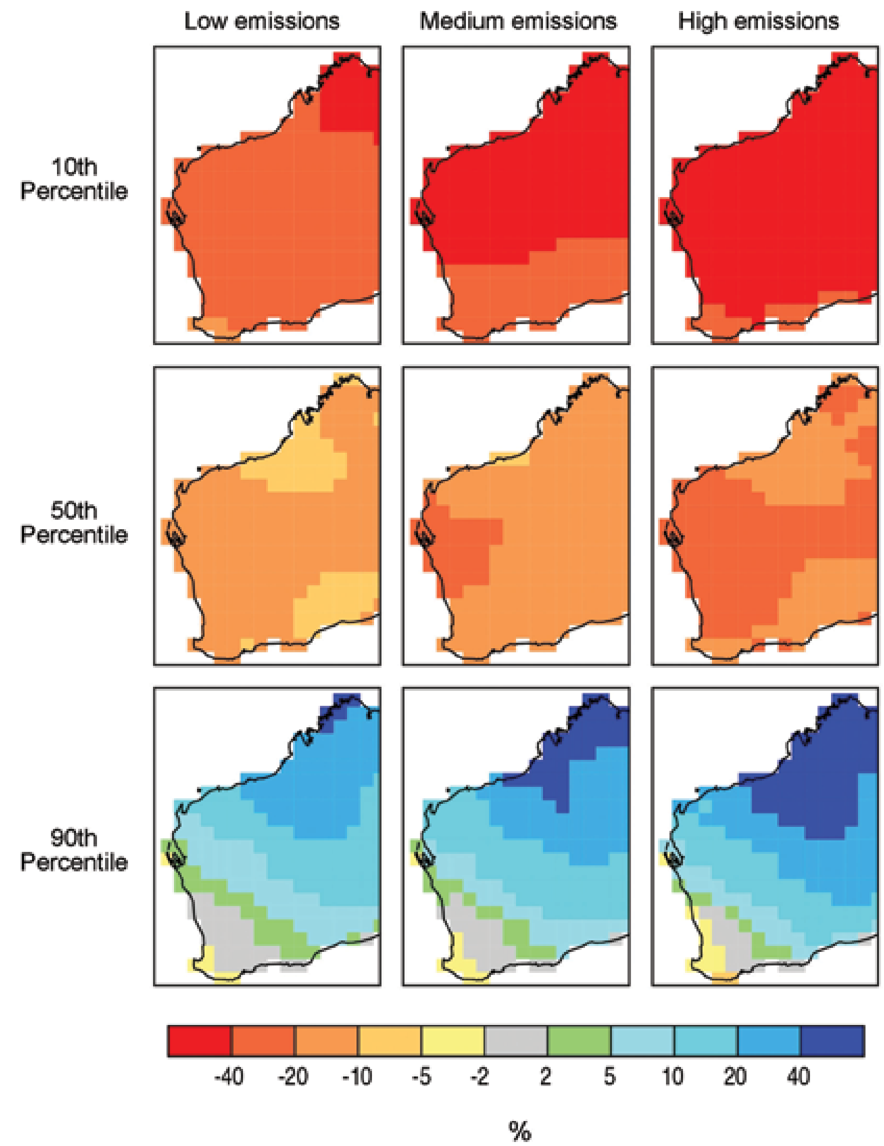
Storms, Droughts, and Bushfires

The Perth region has experienced fewer winter storm fronts over the last three decades, and climate change may result in further declines. Projecting how climate change will affect storms, in particular cyclones, is quite difficult. However, climate scientists currently believe that the cyclone frequency in North West Western Australia is likely to decline, although their relative intensity may increase. Occasionally cyclones from the state's northwestern region travel as far south as Perth. While likely to happen less often in the future, risks will increase that those cyclones that do reach Perth will be more severe and cause more damage.

Furthermore, a rising sea level of 0.5 m in coastal areas will increase the probable return rate of high sea level events, such as storm tide surges, by 100 times in the Perth/Fremantle area. For example, with just 0.5 m sea level rise, storm tide surges that occurred once in 100 years in the twentieth century could come to occur annually (ACE CRC 2008). This shift in probabilities will have dramatic implications for coastal erosion and recession.

An assessment of the recent history and future projections of drought in Australia reported that if the rainfall in South West Western Australia declines by 10 percent by 2030, the risk of droughts will triple. A 20 percent rainfall decline would create a six-fold increase in the risk of drought (BOM and CSIRO 2008). Both of these levels are within the range of rainfall decline that

Figure 9.8 Rainfall Projections for Western Australia in 2070
Source: BOM and CSIRO (2010b).



climate change models have projected for Perth. The Water Corporation (2010) has recognized this risk in its 50-year plan for Perth's water supply, basing its planning on a scenario of a 20 percent decline in rainfall by 2030 and a 40 percent reduction by 2060.

Due to the combination of climate, topography, and vegetation, many regions in Australia have some of the most severe fire climates in the world, and many factors contribute to the risk of severe bushfires. If existing bushfire-prone areas become hotter, drier, and/or windier due to climate change impacts, the risks will increase (Bushfire CRC 2008). Observed decreases in rainfall, increases in temperature, and more frequent very hot days have already increased bushfire risk around Perth, and climate change projections suggest that these risk factors will continue. Increased lightning frequency, a key cause of fires, is associated with increased storm activity. In 2011 Cyclone Yasi, a Category 6 storm, crossed the Queensland coast of Eastern Australia and created extensive property damage there before sweeping across 3,000 km and causing severe easterly winds around Perth, where 72 houses on the Darling Scarp were burnt to the ground.

Mitigation Responses

Western Australia has a rapidly expanding economy, with almost limitless resources and relatively few people. Over many decades, it also has established a strong environmental record and a substantial and growing number of national parks—the most recent of which comprises 30 reserves of old-growth forest protected from logging. One reason for this environmental awareness is the region's status as one of the world's biodiversity hotspots because, in part, for 2 billion years it has been largely unaffected by geological or glacial activity. The state has been one of the leaders in developing programs and projects related to climate change mitigation and adaptation that include local, state, and federal government responses and industry and community initiatives.

Local Government

One of the first global climate change programs was the Cities for Climate Protection (CCP), an initiative of the International Council for Local Environmental Initiatives. By 2010 CCP had led to a reduction in greenhouse gases of 4.7 million tons—the equivalent of taking around 1 million vehicles off the road. With federal government support, all 40 Perth-area local governments joined this program in the early 2000s. The City of Fremantle, for example, recently became carbon neutral; it also is committed to demonstrating that an urban wind farm can be established at the port as well as how to achieve low-carbon characteristics in urban regeneration projects.

The City of Perth has been a leader in reaching the highest level of CCP participation and has played a global role as part of the World Energy Cities Partnership. By 2010 its Greenhouse Gas Emissions Reduction Strategy, established in 2001, came close to achieving its target of a 20 percent reduction from 1996 levels. An innovative aspect of this effort is to be part of a national program called CitySwitch Green Office that enables any commercial office to receive advice on energy savings. Another recent strategy in the city center has been to improve walkability and reduce car use. Jan Gehl did a study of central Perth in 1994 and later led other research projects across Australia and in the United States, where he redesigned city centers, making them more human-centered. He returned to Perth in 2008 to assess the city's progress and found increases of 13 percent in pedestrian traffic and 57 percent in use of city spaces (Gehl and Associates 2009).

State Government

In Western Australia grassroots concern about GHG emissions began in the early 1980s, but a strategy for dealing with the issue was not developed until 1991 (WAGCC 1991). The approach followed a state GHG audit, the first of its kind in Australia (Stocker 1991). In 2003 the State Sustainability Strategy was developed as a comprehensive approach to long-term GHG-related issues across 42 areas of government (Government of Western Australia 2003). This program was followed by the Western Australian Greenhouse Strategy in 2004 (Government of Western Australia 2004), which was later complemented by the Premier's Climate Change Action Statement (Government of Western Australia 2007). The Office of Climate Change was established in 2007 to:

- lead development policy advice on greenhouse issues in Western Australia and coordinate government responses to climate change concerns;
- implement the government's program on adaptation to climate change, coordinate the Indian Ocean Climate Initiative, and translate and communicate climate change science for government policies and programs, the community, and industry;
- work across each sector of the economy in conjunction with relevant state agencies to assess GHG abatement opportunities and policy measures;
- work with conservation and natural resource management agencies and organizations to develop and monitor implementation of climate change policies and programs to protect biodiversity, create carbon sinks, and realize other environmental benefits;
- analyze monitoring and reporting data, prepare advice to government officials on trends and issues, and develop standards and methodologies for GHG monitoring, reporting, accounting, and registration;
- provide advice to the Environmental Protection Authority and other statutory authorities on climate change and greenhouse policy;
- coordinate monitoring, reporting, and evaluation of climate change policies and programs across government agencies;
- implement climate change education and communication programs; and
- administer the Low Emissions Energy Development (LEED) Fund, a $30 million leveraged technology fund over five years.*

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* Unless otherwise noted, dollar amounts cited in this chapter refer to Australian currency.

The state government is currently developing a new and updated state climate change strategy that will include an expanded focus on adaptation policy, but a range of policies have been enacted already to assist mitigation, including carbon rights, the TravelSmart and Living Smart programs, and metropolitan planning and public transport initiatives.

Carbon rights. State legislation passed in 2003 enables landholders to claim carbon-trading rights for reforestation of farmland. Much of the wheat belt in the South West region surrounding Perth had been cleared before 1990. Since then major reforestation and revegetation programs have been implemented, and much of this effort has developed carbon credits under the global voluntary trading scheme. A large Japanese energy utility developed a 1,000 hectare (ha) project on 24 properties, using all the best methods of integration with cropping. Other large resource companies have followed this model with extensive integrated tree planting for carbon sequestration.

The Oil Mallee Association was established in 1997 to advise farmers about the multiple benefits of tree crops, such as salinity reduction, biodiversity enhancement, the potential for eucalyptus oil production, and small-scale power generation as well as carbon credits. With funding assistance from Australia Landcare Ltd., by 2009 more than 14,000 ha of mallee eucalypts had been established across 1,000 properties. The improved species, now referred to as an "oil mallee," is a very hardy native tree from the arid stretches of South West Western Australia. It has an extensive root system, and individual trees have been known to last for hundreds of years, making them ideal for carbon storage. This is also an excellent species to harvest because the trees regrow or coppice immediately after every harvest, a process that presumably can continue for decades.

TravelSmart. This household behavior change program was one of the first to achieve real, repeatable results to reduce automobile use. German sociologist Werner Brög developed an approach to travel demand management based in the social capital of communities (Brög et al. 2009). After some early trials in Europe, Brög's approach was adopted for large-scale projects in Perth (Ashton-Graham and John 2006). It has since spread to most Australian cities, other European cities, especially in the U.K., and has been piloted in six cities in the United States.

TravelSmart has become a national program in Australia with a new $20 million project to reach 300,000 households in Brisbane, SEQ. The approach directly targets households, seeking their participation in the program through a letter from the mayor or state minister, and the funds usually are provided via a partnership of local and state authorities. Follow-up phone calls elicit a household's interest in receiving information and a potential visit from a TravelSmart officer. The trained officers (usually people with a real interest in sustainable transport) arrive at households by bicycle, towing a trailer of material, including specially designed TravelSmart bags with walking and transit information, free tickets for the local transit system, and pamphlets on why reducing car travel is good for the health of family members and the planet. The officers encourage people to start by limiting the number of local trips, especially school trips for children, which are seen as an essential part of the healthy development of a sense of place and belonging in any community.

Communities where TravelSmart has been conducted show a consistent reduction in vehicle kilometers traveled of 12 to 14 percent, and this pattern seems durable for at least five years after the program is introduced. In places where transit is not readily available and destinations are more spread out, the program may reduce car use by only 8 percent; those locales where extensive transit is available, however, have witnessed reductions as high as 15 percent (Ashton-Graham et al. 2005). While this outcome is not revolutionary, few "silver bullet" actions can transform transport's impacts more significantly.

TravelSmart also has many positive synergistic outcomes. People involved in the program become dedicated advocates of sustainable transport, often telling their friends how much better they feel after bicycling or walking or taking transit instead of driving. They also share how they have saved money and how they feel better about doing their part to combat global warming and counter oil vulnerability. Evidence in Brisbane when the surveys were conducted showed that many who followed the program had not been involved in the initial household interviews, indicating that friends and colleagues were spreading the message and expanding the number of participants (Ker 2008).

When people start to change their lifestyles and see benefits as a result, they are apt to become advocates for other sustainable transport policies. As communities begin to change themselves, governments find it easier to manage the politics of such transformations. For example, Perth has been rebuilding its rail system over the past 20 years as a result of a strong social movement that demanded improvement (Newman 2011). Now extended to 172 km, patronage of the rail system has increased from 7 to 55 million over a 17-year period. It is relevant that, parallel to this infrastructure-building process, Perth had some 330,000 households participating in the TravelSmart program. The suburbs involved in TravelSmart had significantly higher use of the new train line, and it has become an icon across Australia for other cities that are now determined to upgrade their rail systems. A report sponsored by the Organisation for Economic and Community Development stated that improved acceptance of hard measures, such as taxes and expensive infrastructure, is the prime benefit of soft measures, like TravelSmart (Salzman 2008).

The TravelSmart program is making clear a fundamental principle about behavior change—it works best when supported by a community and is part of the development of social capital. TravelSmart develops its social capital by promoting sustainable transport modes rather than the dominant automobile culture and by establishing relationships between the TravelSmart officer and others in the local community who take the first steps to get out of their cars. In workplaces, the program works well when a TravelSmart club is formed to enable people to share experiences, sponsor local speakers, and lobby employers for facilities such as showers for bike riders and transit passes instead of parking spaces. When a city's government program facilitates a social movement for more sustainable transport options, that city can then begin to imagine its realization of a more sustainable future.

Living Smart. The same approach to changing travel behavior has been applied at the household level to aspects of sustainability, such as how to reduce waste and use of energy and water. A program known as Living Smart began in Perth, and similar approaches are developing across Australia as climate change emerges as a major political force. The Perth program, under the auspices of the state's Department of Transport, builds on the success of household education and social capital by one-on-one discussions in residents' homes of educationally sound and locally relevant material. The eco-coaches have worked in 30,000 trial households and found enormous enthusiasm from those who had been looking for this kind of targeted assistance. A cold-call process yielded some 80 percent of households expressing interest in making changes to improve energy, water, waste, and travel sustainability. Of those households, 50 percent have been signing up for continued coaching on special water meters, gardening, and home audits.

Unlike TravelSmart, where change tends to occur slowly and incrementally, the Living Smart program receives reports from households that have made instant, radical changes, such as replacing inefficient lights and installing photovoltaic panels (PV), solar hot water systems, and greywater recycling systems. The program is on track to reduce CO_2 by 1.5 tons per household annually from an average in Australia of 14 tons per household. This reduction will save the households more than 10 percent on their gas, electric, water, and petroleum bills (Department of Transport 2009).

The social capital being built up around these new technologies and lifestyles is also proving highly infectious, and it can become the basis of a major social movement if governments are prepared to adopt the approach more broadly. At low cost to the government, the reduction of household GHG has the potential to make a major contribution to climate change mitigation policy worldwide.

Metropolitan planning and public transport. The state government of Western Australia has had a bipartisan approach to regional planning for 50 years, and it wields full planning powers to enable strategic and statutory planning at the local government level to be coordinated with metropolitan Perth and other regional centers. For most of the past half-century, the region has been built around the car, but it has also implemented an extensive open space system as well as the reclamation of all foreshores and beach frontages.

In recent times the urbanized area has begun to accommodate public transport more extensively and to facilitate more integrated, less car-dependant land uses. The revival of the metropolitan rail system has been very successful through electrification and extension of fast rail along several corridors, providing 172 km of rail with 32 stations. The state is now committed to increasing the number of transit-oriented developments (TODs) around these stations, and its Directions 31 plan provides population and job targets for these centers. A public transport strategy is being prepared to plan the next stage in this integrated approach to future development. Several TODs, such as Stirling City Centre, are designed to be model developments of low carbon use.

Federal Government Programs

The federal government also has created a number of climate change mitigation programs that are being demonstrated in Perth and its bioregion.

Solar cities. Perth's eastern suburbs were chosen to demonstrate how to make renewable energy part of the future city. This program is an opportunity not only to provide several thousand homes with PV, but also to test how these systems, along with smart meters and electric vehicles, can work together to exemplify a renewable city (Droege 2009; Went, Newman, and James 2009).

Energy efficiency and household assessments. An offer of free insulation enabled 950,000 homes in Australia—90,000 in Perth alone—to become much more energy efficient. Subsidized PVs were built into these grants as well. Householders can have a free assessment of their energy and water use and receive a trained assessor's house-specific recommendations for actions that will improve their home's sustainability.

Renewable energy target. In August 2009, the Federal Government implemented its Renewable Energy Target (RET) scheme, which is designed to deliver on the government's commitment to ensure that, by 2020, 20 percent of Australia's electricity supply will come from renewable sources. In June 2010, Parliament passed legislation to separate the RET into two parts: the Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES). The changes provide greater certainty for households, large-scale renewable energy projects, and installers of small-scale renewable energy systems. This statutory requirement for utilities has led to some $20 billion of investment in wind farms, solar PV, and other renewable projects across Australia. A new wind farm has joined three existing ones in the Perth region, and together they bring the city's renewables contribution to 9 percent of the electricity grid.

Industry

Western Australia is the center of a major gas production area. The Gorgon Gas Field, the most recent project to be approved, was controversial because it is using Barrow Island, an A-class reserve, as the location where gas is brought onshore and processed for export. One reason for development of this site is the availability, deep under the island, of geological formations that enable CO_2 to be pumped down and stored, or "sequestered." The government of Western Australia has required Chevron and its joint partners, the $43 billion project's proponents, to design and construct a carbon capture and storage (CCS) system that will be one of the largest of its kind in the world. Perth will supply most of the labor and receive substantial amounts of energy for space heating, cooking, and electricity generation, resulting in lower GHG emissions than realized from the use of coal, the region's other major energy source (Barnett 2009).

Nongovernment Organizations

One of the largest and most visionary nongovernment organization (NGO) initiatives in climate change has been rebuilding a 2,000 km natural link from one side of the state to the other. This project, known as Gondwana Link, is revegetating farmland to connect reserves from the coastal Karri forests to the inland Kalgoorlie woodlands. It will create a biodiversity corridor to encourage long-term species survival under climate change pressures and will provide an opportunity for farmers, industry, and NGOs to work together. First envisaged by the Wilderness Society (in consultation with the Nature Conservancy), the project now has partnerships with groups such as Greening Australia and Men of the Trees. Industry has been a substantial contributor through carbon credit processes being developed for biodiversity planting along the reserve. Gondwana Link also provides an opportunity for Perth residents to buy carbon offsets.

Another Perth NGO, Days of Change, challenges householders, businesses, sporting clubs, and others to pledge various levels of GHG reductions personally. Its growing support base recently resulted in 40 percent of the residents in the nearby town of York to commit to substantial reductions in GHG use.

Many households are not waiting for government, industry, or even NGOs to help them contribute to climate change–inspired reductions. In South Fremantle, Hulbert Street residents Shani Graham and Tim Darby decided they would help make their street sustainable and have fun doing it. In just two years, the permaculture-based system for growing vegetables they have developed now involves nearly every household on the street. In addition, more than 20 percent of households have installed PVs on their roofs; a skills register enables people to share tools, trades, and tasks; a bicycle freight system is used to carry items between houses; a Hulbert Street choir has been started; most residents have taken a Living Smart course; and some residents now are taking the program to other streets. Each Friday night Hulbert Street is closed off for outdoor movies on relevant topics, and each year the residents' Sustainability Fiesta attracts thousands of visitors, who come to see how one street is setting—and meeting—its own goals for the future.

Adaptation Responses to a Drying Climate

Indian Ocean Climate Initiative

In the 1990s many residents in the Perth region expressed considerable resistance to the idea that reduced rainfall could be due to climate change. They preferred the explanation that the reduction was simply natural variability in the weather, because that interpretation implied the decline in rainfall was temporary and higher rainfall levels would return eventually. The doubters further advised caution toward and delay in investing in adaptations to the public water supply system that might address the potential of a permanently reduced rainfall scenario. Substantial public debate continued during that decade over whether natural variability, climate change, or some combination of the two was responsible for observed rainfall declines.

The Western Australian state government acknowledged the decreased rainfall and projections that climate change may cause further reductions, and it recognized the need to understand the causes better. In 1997 the government established a climate science research program with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Australian Bureau of Meteorology (BOM), the two premier climate science research institutions in the country. This collaboration, called the Indian Ocean Climate Initiative (IOCI), has led three successive four-year-long research programs, each based on separate funding and service agreement contracts. The results of IOCI Stages 1 and 2 have been pivotal to public policy making in Western Australia and influential in the national climate science and policy scene. Numerous reports and papers have concluded that climate change is a significant contributor to the reduced rainfall experienced (IOCI 2009). IOCI Stage 3 was completed in 2011.

IOCI research played a key role in convincing decision makers to commit to large, additional public investment in water source developments, even while many voices still argued that such investment should be delayed. Perth, therefore, compares favorably to other Australian capital cities that have experienced reduced rainfall more recently, but it still had to introduce full water restrictions because its public water supply systems could not cope with the reduced water storage in their dams. The value of the IOCI's work has been recognized widely, and many other Australian states have now established similar dedicated climate research programs, in particular the South Eastern Australian Climate Initiative.

Water Resource Planning

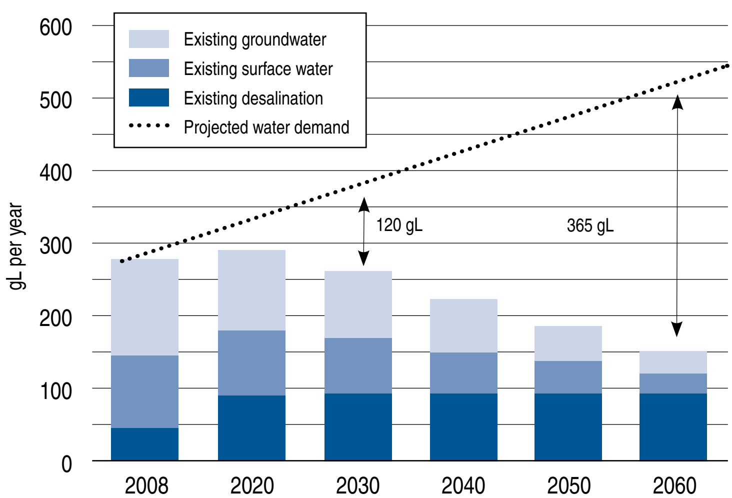
Relevant predictions indicate that under a climate changed future the rainfall levels in the Perth region will continue to decline, the city will be populated by roughly twice its current number of residents, and the environmental impact of water provision will need to be reduced. The Water Corporation, which has primary responsibility for planning water supply and storage in Western Australia, has made major investments in systems to pump groundwater from major aquifers near Perth. During the 1980s and 1990s these efforts diversified the sources for the public water supply system and expanded the proportion of water being sourced from groundwater. Reduced rainfall also resulted in a decrease in groundwater recharge, thus reducing further the sustainable water yield that can be pumped from the region's major groundwater resources.

When a severe drought started in 2001, more than 50 percent of the public water supply was sourced from groundwater. The growing awareness that climate change was likely to cause further declines in rainfall, however, caused many officials to recognize the value of diversifying water sources to include those that are independent of rainfall. Thus the state government committed to building the largest seawater desalination plant in the Southern Hemisphere. Australia's first large-scale plant cost $387 million and began operation in 2006. Since that initial commitment, four other Australian states have made investments in desalination plants. With the construction of a second large seawater desalination plant to supply Perth, the city will obtain 40 percent of its water supply from desalination. Wind powers all of these plants.

The rainfall reduction led the Western Australian state government to invest a total of $673 million in 10 separate water source development projects between 1996 and 2006, and it has increased water supply capacity by a total of 199 gL (Water Corporation 2010), compared with total water use of 286 gL in 2008 (Water Corporation 2009b). To accommodate for both declining rainfall and increasing population, the Water Corporation has forecast that Perth and its connected towns will need an extra 365 gL of drinking water by 2060 (figure 9.9). In a strategic study, the Water Corporation (2009b) identified this three-part strategy for meeting Perth's water needs in a changing climate:

- reduce water use by 25 percent per capita;

Figure 9.9 Gap Between Perth's Water Supply and Demand to 2060
Source: Water Corporation (2009b, 7).



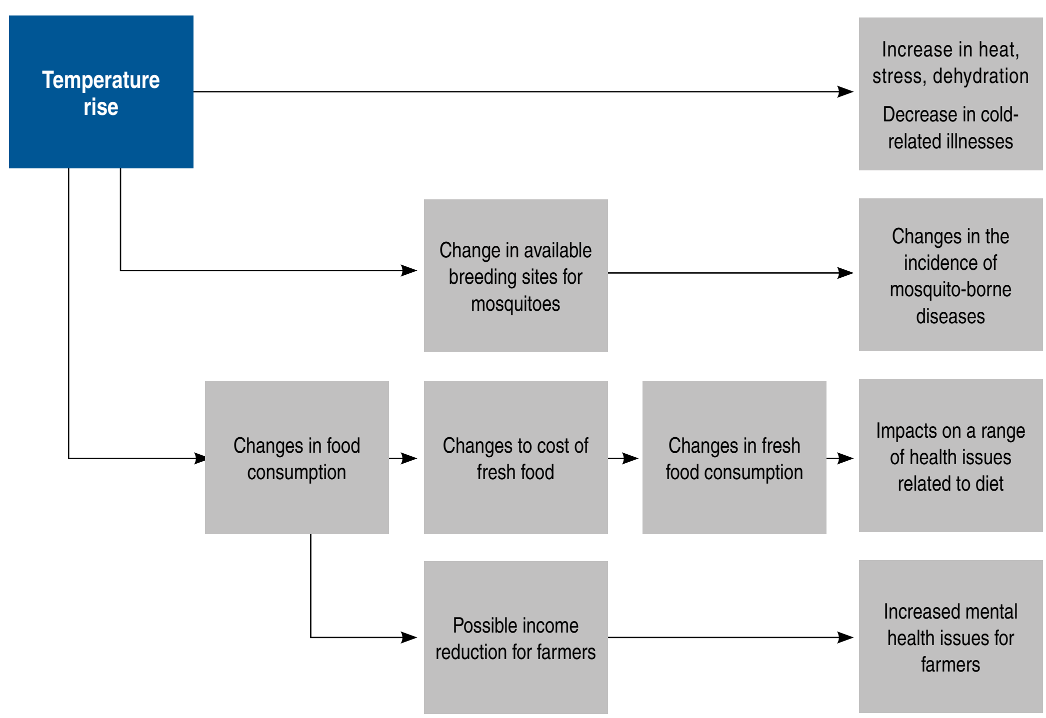
- increase the proportion of metropolitan water that is recycled from 6 percent to 60 percent; and
- develop new sources, primarily more desalination plants.

Public Health

Western Australia's Department of Health has recognized that climate change represents a significant and growing threat to public health, with impacts resulting from extreme weather events, air pollution, water- and food-borne diseases, vector-borne diseases, and indirect effects on mental health. In partnership with Curtin University, the department produced an initial study of climate change induced health issues (Spickett, Brown, and Katscherian 2008). The two-phase project sought first to identify potential health impacts that could result from a scenario of climate change in the context of the region's current ability to cope and the existing socioeconomic vulnerabilities, such as temperature rise (figure 9.10). The second phase involved a risk assessment, which found that the lack of detailed information made a quantitative study impossible. Use of a qualitative review, however, established a good understanding of current activities,

Figure 9.10 Potential Health Impacts of Temperature Rise

Source: Spickett, Brown, and Katscherian (2008).



their adequacy with respect to health, and a range of desirable adaptations and supporting research. This research provides the basis for an active approach to protecting the community from climate change impacts and future planning and adaptation.

Local Governments and the Eastern Metropolitan Regional Council

Under the hotter, drier conditions projected for Perth, bushfires, declining water availability, and waterway health present a range of hazards that will only increase. The consequences are too great for local governments to handle alone, so a regional approach has been adopted in one cutting-edge adaptation process, in which local governments of metropolitan Perth are grouped together into regional councils to provide services such as resource recovery, environmental management, regional development, and risk management. The Eastern Metropolitan Regional Council (EMRC) comprises six member councils, which collectively cover one-third of the metropolitan region and include large stretches of native forest and bushland. These areas are especially vulnerable to the impacts of bushfires on human life, ecosystems, infrastructure, industry, and homes. The river systems within them, and water availability generally, are also under pressure from drying conditions.

The EMRC developed an idea for a regionally based climate change adaptation plan and obtained funds from the Local Adaptation Pathways Program of the Australian government's Department of Climate Change. The EMRC also contributed core funding. The framework, known as Future Proofing Perth's Eastern Region, was developed to complement regional mitigation actions by identifying the major climate change risks and providing assistance with developing a regional adaptation plan to address them. Key stakeholders and decision makers held a regional forum in February 2009, and ongoing consultation and data collection has included a series of workshops with the member councils' staffs to ensure effective and relevant inputs into the risk assessment and asset identification process.

Perth's future proofing process developed a Regional Climate Change Adaptation Action Plan for 2009 through 2013 (EMRC n.d.). It has been approved by the EMRC and is now operational. The EMRC and its six member councils have provided four years of funding and commitment to help ensure that the recommended actions actually are implemented. Ten priority risk areas were identified by the EMRC project.

1. Infrastructure failure
2. Impacts on essential services
3. Watercourse damage and loss
4. Fire

5. Water decline and quality
6. GHG emissions and related air pollution
7. Ecosystem loss and public open space
8. Population health and displaced people
9. Economic decline
10. Changing leadership and development requirements

The EMRC is in the process of implementing actions, including:

- identifying existing information gaps and partnerships regarding the impacts of climate change on local government infrastructure (i.e., roads, paths, drainage);
- investigating current research and directions on power and fuel supply solutions and technologies;
- raising community awareness and behavior change toward riverbank erosion and subsidence issues;
- advocating that the state fire and emergency services authority support better fire management measures;
- raising community awareness about how and when residents should protect their houses to ensure that fire warning systems are in place;
- promoting water-efficient appliances, rainwater tanks, and greywater use; and
- advocating that state government produce a policy on climate change.

All six member councils have been motivated by the future proofing project and are now in the process of developing their own local climate change adaptation action plans based on various forms of risk assessment. The EMRC is also sharing its best management practices with other regional councils such as the Western Suburbs Regional Organisation of Councils. Naomi Rakela, EMRC's manager of environmental services, has said it is logical and beneficial to deal with climate change as a two-level—regional and local—planning strategy in order to ensure that all the risks are captured and provide for a more holistic approach (personal communication, 18 March 2010).

Online Climate Management Toolkit

The Western Australian Local Government Association (WALGA 2009), funded by the Commonwealth of Australia's Department of Environment and Conservation, commissioned the Curtin University Sustainability Policy

Institute (CUSP) to build an online Climate Change Management Toolkit. Its purpose is to provide a set of resources and guidelines to local governments to enable them to respond to climate change concerns. It takes the user through a series of required actions and includes a set of resources for each step. The toolkit has been introduced to a large number of local governments, where it has been well received.

Adaptation Response to Coastal Risks

Perth Coastline

As in most places in Australia, indigenous people in Perth have interacted with the continent's coast for tens of thousands of years. There are many cultural stories about the Nyungar (Noongar) occupation of land that is now under water between Perth and Rottnest Island. As told by Dr. Noel Nannup, "When the Sea Level Rose" recounts the impact of such a catastrophe on his forebears, probably at the end of the last ice age some 7,000 years ago. The narrative follows Nyingarn the Echidna and Kaarda the Goanna as they cared for the spirits of those who had passed away. Wadjemup (Rottnest Island), when it was connected by a land bridge to the mainland, is described, and Mamong the whale and Kieler the dolphin, who helped Nyingarn and Kaarda, are introduced. The story centers on a time when the sea level rose and trapped the spirits of children underneath the sea. Mamong and Kieler helped bring the children back to the land (Nannup 2006).

Many coastal indigenous peoples of Australia have dwelt as clans that share some common features. Coastal clans use marine resources for subsistence, culture, and exchange, and rather than being radically discontinuous, they consider their "saltwater country" or "sea country" to be inseparable from the land. Cultural stories describe the features of sea country, and some names and sacred sites reflect these places, reinforcing clan identity closely tied to the sea. Clans manage their estates through cultural ceremonies, with song and dance, and traditionally they restricted access to the sea according to the season, status of clan member, totem, and presence of sacred sites (Smyth 2004).

Many of the names of islands and coastal features around Perth relate to these cultural or "dreaming" stories (WAPC 2008, 54).

> Present-day Noongar oral history confirms the importance of the coast, the sea and the islands. In a restricted report made available to the AIC, several Noongar elders recounted Dreaming stories for the coast from Fremantle to Yanchep. In one version Crocodile, Shark and Whale encountered one another. Their fighting altered different parts of the landscape. Whale is associated with sand dunes at Leighton Beach. Shark and Crocodile fought in Cockburn Sound until the Creation Snake "Waugal" intervened. Crocodile on Waugal's advice travelled

> to Yanchep where he metamorphosed into Emu (Waitj).... In another Dreaming story, a fight between Crocodile and Waugal broke up the land and created Rottnest, Garden and Carnac islands.... The Waugal is regarded as having created the sand dunes that follow the coast, as it has for all land features.

Since white settlement of Western Australian, human uses of and impacts on the coastal zone have increased dramatically, and more than 80 percent of the state's population currently lives within 30 kilometers of the coast. The variety of landforms and patterns of human usage of the contemporary coastline include:

- urban coasts characterized by intensive residential, commercial, and industrial development, usually with high recreational usage;
- natural coasts with light residential and commercial usage with access for tourism and recreation; and
- wilderness coasts with little or no residential, commercial, or industrial usage, and little access to tourists.

The Perth shoreline is largely urban, with some natural coasts to the north and south of the metropolitan area. As the city expands, the conversion of coasts from natural to urban form is unfolding quickly, with much new development occurring close to the primary dunes. Western Australians value a coastal lifestyle and the unique opportunities that the shore provides. Perth's coastal waters are still relatively clean, and residents swim, dive, surf, fish, picnic, sail, and walk their dogs on the shore. For a holiday, they are most likely to visit another coastal location such as Rottnest Island or the Margaret River area. However, pressures on the coast are increasing from rapid population growth and development; catchment land and water use; marine industries (shipping, tourism, aquaculture, oil and gas extraction, tourism, and fishing); pollution; exotic species; and coastal infrastructure development. Climate change and extreme weather events have begun to interact with these existing pressures.

Governance of the coast is a challenge because it is characterized by multiple jurisdictions, a lack of integrated management tools, and continuing controversy over major developments. Perspectives on what constitutes appropriate coastal zone management and adaptation to climate change differ according to the jurisdictions' and stakeholders' worldviews and values (Kellert 2003; Stocker and Kennedy 2009).

State Coastal Planning

Western Australian State Planning Policy No. 2.6: State Coastal Planning Policy (SPP 2.6 2003) is the principal policy instrument for guiding new land developments in coastal regions. The policy's objectives are to:

- protect, conserve, and enhance coastal values, particularly in areas of landscape, nature conservation, indigenous, and cultural significance;
- provide for access to public foreshore areas;
- ensure the identification of appropriate areas for the sustainable use of the coast for housing, tourism, recreation, ocean access, maritime industry, and commercial and other activities; and
- ensure that the location of coastal facilities and development takes into account coastal processes including erosion, accretion, storm surge, tides, wave conditions, sea level change, and biophysical criteria.

Under a climate changed future, the first three objectives can be met only if the final one is accomplished. To achieve all its objectives, SPP 2.6 2003 relies on the use of measures to guide regional and local coastal planning; strategic coastal planning prior to development of an area; and development setback guidelines. Schedule One of the policy includes guidance on coastal setback requirements in relation to the potential impacts of climate change, sea level rise, and the dynamic nature of coastal processes, including the calculation of distances for absorbing extreme storm sequences and acute erosion and for allowing for historic trends and sea level change.

Although setback calculation varies according to factors such as coastal geomorphology, a total setback on the order of 100 meters from the horizontal setback datum is expected. This has proved to be a highly controversial aspect of the policy, resulting in struggles among government, developers, local residents, and conservationists over access to and use of the foreshore. A more defensible sea level rise formula is being developed, but the fundamentally complex and uncertain nature of climate change and sea level rise challenges the core goals of instrumental policy making and planning. The need for reflexivity and adaptive planning is critical.

Other ongoing coastal planning initiatives include the LiDAR/Airborne Laser Bathymetric survey of the coast from Two Rocks north of Perth to Cape Naturaliste in the southwest corner of Western Australia. This information will be used to support decision making on the coast, taking into account the effects of storm surge and sea level rise. The baseline modeling will ensure identification and better management of areas at risk of coastal inundation and/or flooding and the combined effects of storm surge and high winds.

Following a public engagement process, a coastal planning strategy for Perth is also underway. Its aim is to provide a regional overview, with strategic planning and policy guidance for dealing with development on the metropolitan coast. Considerations include coastal issues; environmental (terrestrial and marine) concerns; urban, commercial, and industrial uses; the place of tourism, recreation, and public use and access; and visual, landscape, and cultural issues. Public submissions on the draft strategy highlighted the importance of climate change and the subsequent impact of sea level rise and associated concerns with coastal erosion. The final strategy will be an important planning tool for state and local government and other agencies to guide future planning decisions.

Local Government Coastal Vulnerability Assessments

Understanding the implications of locating development in particular areas is critical to managing and mitigating the impacts of climate change, including sea level rise and inundation, storm surge events, and erosion. Vulnerable areas in the Perth metropolitan region include Trigg, Rockingham, Cottesloe, and Mandurah.

The town of Cottesloe, for example, includes one of Perth's favorite and most iconic beaches, which is a major regional attraction for surfers, club goers, sunbathers, families, and coffee drinkers. An annual sculpture festival on the foreshore in March celebrates the interaction of culture and nature and attracts tens of thousands of visitors. Cottesloe Beach faces potential risk from coastal erosion, as development is very close to the present shoreline, with some structures built right on the beachfront. In response to this threat, the Town of Cottesloe (2008) commissioned a report to help officials prepare for future challenges in the management and maintenance of its valuable coast, resources, and infrastructure. The main aim of the report was to establish the potential risk to key existing coastal infrastructure under a range of future climate scenarios and to suggest adaptive pathways. The study found that the most extreme prediction of the modeling process was a shoreline recession of 97 m, which would destroy the main road and the front rows of houses.

Similar studies are underway for other areas in Geographe Bay, an exceptionally vulnerable region with an erosive coastline, large estuarine systems of great ecological and cultural value, and wealthy canal estates. Several local governments in the region are eager to undertake serious climate change adaptation.

Community-Based Adaptation Planning

In July 2009, in Fremantle, CUSP ran a community workshop at a site of early white settlement. Once a Labor Party stronghold, this port town now has an increasingly Greens-leaning electorate and a strong economic base that includes a university, tourism, arts, and designer fashion.

The daylong workshop used Google Earth and deliberation as the key consultation tools. The 150 participants listened to a series of short talks from scientists about the likely impacts of climate change on the Fremantle coastal zone. Local and state government speakers presented the governance perspective, and panel sessions provided time for questions and answers. Participants in groups of eight met around tables and used large physical maps of coastal Fremantle to choose five places of particular importance to the group and identify their values and uses for each of these places. Next they deliberated about their principal concerns regarding the likely impact of climate change on their chosen sites. Finally, they discussed the possible adaptive pathways that should be considered as responses to their concerns.

All of the groups' deliberations were summarized at each stage and place marked in Google Earth, thus providing a spatially explicit account of the process; these results were compiled into a single file on the CUSP Web site. The workshop, the first of its kind in Western Australia, allowed residents, scientists, policy makers, planners, and academics to sit together and work through the major climate adaptation issues facing Fremantle. CUSP will undertake similar workshops for Rottnest Island, Perth's favorite island holiday destination, to help plan for its sustainability and climate change; Geraldton, a coastal town to the north; and Mandurah, a highly vulnerable and rapidly growing city south of Perth.

Federal Research Initiatives

CSIRO is concerned that progress in coastal adaptation governance has been too slow, even though researchers have generated substantial scientific data and models detailing coastal climate change consequences, and both lay and traditional knowledge systems report on these impacts as well. Therefore, CSIRO funded a major new research initiative led by Curtin University, the Coastal Collaboration Cluster, to identify ways of enabling better use of climate change science by decision makers in the coastal zone (Stocker et al. 2010; Wood and Stocker 2009).

The cluster's working model indicates that, in addition to favorable functions and processes in the broad sociocultural context, good governance requires both a receptive governing process and accessible knowledge systems. Adaptive learning, especially in the complex and uncertain domain of coastal management, can enhance this dialogue. Governance includes the institutional authorities, processes, and procedures used for guiding strategic and key operational decisions about the coastal zone. As mentioned above, coastal governance in Australia comprises not only complex interacting levels of formal government (federal, state, and local), but also development commissions, nongovernment organizations, indigenous native titleholders, and a wide range of other stakeholders. Curtin University's research contribution to this cluster addresses which kinds of governance arrangements are most likely to enable adoption of knowledge about coastal adaptation and generate adaptive solutions by drawing on postnormal methodologies, such as transdisciplinary research, digital visualization and Google Earth, deliberative workshops, social network analysis, causal layered analysis, and scenario development.

Conclusions

The attempts by Perth and its bioregion to come to terms with climate change represent a modest contribution to this global issue. Some innovations that could be significant in other countries have been documented in the Perth region, but they are not nearly enough. By sharing these efforts, we hope they can help develop the momentum for mitigation and adaptation approaches that can also benefit other regions.

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Conclusion

Transpacific Perspectives on Climate Action

Edward J. Blakely and Armando Carbonell

Coastal cities and states in the United States and Australia are stepping forward, in many cases well ahead of other developed nations and the international community, both to mitigate and adapt to climate change. During the course of our work on this book, expectations for climate action on the international level have been lowered, beginning with the 2009 United Nations Framework Convention that produced the disappointing, nonbinding Copenhagen Accord. At a subsequent meeting in Cancun, Mexico, in 2010, the convention agreed to create—but not pay for—a Green Climate Fund and Climate Technology Center and made little progress on mitigation targets. The 2011 Framework meeting in Durban, South Africa, although lacking in definitive action, saw progress in implementing the agreed-upon $100 billion Green Climate Fund, extended for five years the Kyoto Protocol, which had been due to expire in 2012, and moved closer to a binding agreement on a global legal regime for climate by 2015. However, Canada's withdrawal from Kyoto one day after the conclusion of the Durban meeting cannot be seen as a positive sign.

It is notable that *The Guardian* included the following dramatic headlines in its environmental news of the week shortly before the Durban meeting started: "World Headed for Irreversible Climate Change in 5 Years, IEA Warns"; and "Australian Senate Passes Carbon Tax." The first article refers to a finding by the International Energy Agency that over the next five years the lock-in effects of new fossil fuel power plants, factories, and inefficient buildings will result in disastrous and irreversible climate change. The second article notes the passage by Australia's parliament of an AU$23-per-ton carbon tax on the country's 500 largest greenhouse gas (GHG) emitters, effective July 2012. *The Guardian* (2011a) lauds the vote as a victory for Prime Minister Julia Gillard in that it creates "the most comprehensive carbon price scheme outside Europe." Former Prime Minister Kevin Rudd had staked his government and political career on climate action with a proposed carbon-trading scheme that later collapsed, and he was forced to step down in mid-2010.

Meanwhile, in the United States, issuance of rules to limit GHG emissions from power plants and other large polluters has been delayed since the U.S. Environmental Protection Agency missed its September 2011 deadline for issuing new rules on GHG emissions. The 111th Congress (2009–2010) permitted legislation dealing with climate and energy to die, and at this time no serious prospects for revival can be foreseen.

The pivotal environmental issue of our time has largely been pushed off national stages as governments around the globe struggle for economic stability in the wake of the financial crisis of 2008. In spite of mixed prospects for action at the international and national levels, state and local governments have shown a greater ability and willingness to respond to climate change. In public discussions, resilience and adaptation are coming to the fore, and increasing attention is being given to the impacts of changes in climate on human welfare and the integrity of ecosystems. Local governments are finding champions for higher-density settlement patterns and increased public transit. Both New York City and the state have embarked on an ambitious plan to increase their resilience to climate change. Melbourne and Sydney are moving ahead with increasingly bold urban revitalization plans that incorporate many climate change adaptation strategies, including requirements for water retention, increased use of energy-saving devices for all new homes, and a variety of inducements to retrofit existing buildings.

With drought followed by extreme flood events, Queensland is experiencing its worst weather swings in recorded history, thus reinforcing the political will to act to protect sensitive areas from climate volatility. At the same time, however, desalination plants, which entail notable GHG impacts themselves, are being built across Australia in anticipation of more severe droughts. In the United States, the BP Deepwater Horizon oil spill of April 2010 led to increased cooperation among the southeastern states with coasts on the Gulf of Mexico. The oil spill heightened recognition of these areas' increased vulnerability to environmental damage. The destruction of wetlands and loss of habitat portend potential disaster for inhabited areas as the chapters on the southeastern Atlantic states from the Carolinas to Florida and on New Orleans ably demonstrate.

While a variety of arguments and rationales can be advanced for change in urban spatial arrangements and planning regimes, some of the urban transformations beginning to emerge in the United States and Australia clearly are aimed at dealing with the risks of climate change. Moreover, it is apparent that each country is learning from the other. Study tours, conferences, and other means of sharing experiences are driving a common set of themes in the major cities discussed in this book, which we hope will make its own contribution to new understanding.

In each of our coastal city cases, a trigger event or set of events and conditions can be associated with problem recognition that leads to action. In Los Angeles, where the Southern California Association of Governments represents more than 18 million people living in 6 counties and 191 cities, a patchwork water system initially designed to accommodate only a few million people is now seriously stressed due to population growth and the effects of climate change that have caused a decline in distant water supplies. The sources and systems that supply water to the Los Angeles basin from the Colorado River, eastern Sierra Mountains, and California Delta are exceedingly fragile. Rampant fires may signal impending catastrophe, as the second-largest metropolitan area in the United States faces the prospect of simply running dry, even while rising sea levels, extreme tides, and storm surge threaten the coast. Through legislation and executive order as well as at the ballot box, the state of California has responded vigorously and now requires regional approaches to mitigate GHG emissions and encourages communities to become more resilient to the unavoidable effects of climate change. Across the Pacific, in Queensland, the state government and local government authorities are concerned with many of the same forces at work in Los Angeles and are taking action to deal with similar extreme conditions.

A new-found recognition is emerging that the landscape entailed within a "climate region" is larger than the jurisdictional boundaries that were created in earlier times. The entire central area of Australia is a single climate region with similar conditions prevailing over millions of square kilometers of the land mass. The Murray-Darling River provides water for crops and human consumption across four states and the Australian Capitol Territory. Similarly, New York City and the Hudson River Valley to its north belong to a single watershed, but jurisdictions throughout the metropolitan area were carved up with scant attention to water or other natural systems. This watershed and others in both countries lack governance arrangements sufficient to the task of effectively addressing volatile climatic conditions. We see the impacts on fragile ecologies in Queensland, in California, and especially in New Orleans at the mouth of the mighty Mississippi River. While the search for better governance structures for these natural systems is a consistent theme in *Resilient Coastal City Regions*, so is the awareness that there are no easy answers. While it may not always be feasible to redraw boundaries to reflect ecological reality, new ways of organizing ourselves across space are being developed to deal with an uncertain and risky future.

Both mitigation and adaptation policies are necessary components of a rational societal response to climate change. Because of the long half-life of GHGs released into the atmosphere since the advent of the industrial era, the planet will continue to warm, even if we are able to achieve reductions in future emissions. This means that, regardless of our success with various mitigation measures, we still need to deal with the kinds of impacts described in these chapters. Further, although many of the cities and states examined here have taken important steps to reduce GHG emissions, in the absence of enforceable national and international mitigation targets and robust strategies to achieve them, we cannot expect to avert a range of more extreme climate effects. It is noteworthy that cities and states have stepped up to take the initiative on mitigation despite our failure to date to achieve international consensus or, in the United States, even to craft a national policy.

Adaptation—reducing the impacts of unavoidable climate change—is the main thrust in New Orleans, where more than US$10 billion is being spent to contain the Mississippi River and fend off storm surges from the Gulf of Mexico. Flood damage in New Orleans can be reduced by restoring the pre-twentieth-century deltaic urban form, allowing the river to flow into privately owned properties to restore wetland habitats and relieve pressure on the levees during high river stages. The recently adopted New Orleans master plan and Louisiana's 2012 coastal master plan both recognize the need for this approach, but its implementation will require significant political courage and financial resources.

Similarly, New York City is considering strategies to protect the world financial marketplace in Lower Manhattan, which is highly vulnerable to storm surge. Strategic retreat is now being discussed in northern New South Wales and the Sydney region, as the cost and difficulty of defending existing development is prohibitive. Perth, with 50 percent of its water supply now provided by desalination plants, has recognized the impacts of climate change on dwindling groundwater supplies over two decades. The region's winter rainfall average is now insufficient to fully replenish surface water storage systems. Melbourne and most of the surrounding region have taken an adaptive posture in responding to flood risks in low-lying areas, but the local government has been loath to deny homeowners permission to rebuild in the hills above the city scarred by the devastating Black Sunday fires in 2009. The same can be said for much of Southern California's hill country, where major fires have occurred regularly during the past decade.

Why are cities and states stepping forward, in many cases well ahead of nations and the international community, both to mitigate and adapt to climate change? The benefits of mitigation accrue to the entire planet, so there can be said to exist a "free rider" problem that would argue against local action. However, the economic benefits associated with a wide range of mitigation actions—those providing cost savings from energy efficiency, for example—can be captured locally. And the innovations spurred on by California's aggressive climate policies may position that state competitively as others catch up under future national mandates. Adaptation will continue to be a local imperative as the benefits of action—and the costs of inaction—will, to a great extent, be felt locally.

In publishing this volume, it is our intent to document approaches that will be useful not just in the United States and Australia, but more broadly in coastal regions throughout the world. We are humbly aware that this is only an initial response to a challenge with a magnitude of potential impacts never before experienced in human history, a challenge that will test our ability to work together at every scale, from the local to the planetary.

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