Union of Concerned Scientists

EXECUTIVE SUMMARY

National Landmarks at Risk

How Rising Seas, Floods, and Wildfires Are Threatening the United States' Most Cherished Historic Sites

HIGHLIGHTS

This report presents a selection of case studies that vividly illustrate the urgent problem of climate impacts on U.S. historical places. The stories these sites tell symbolize values—such as patriotism, freedom, democracy, respect for ancestors, and admiration for the pioneering and entrepreneurial spirit—that unite all Americans. Given the scale of the problem and the cultural value of the places at risk, it is not enough merely to plan for change and expect to adapt. We must begin now to prepare our threatened landmarks to face worsening climate impacts; climate resilience must become a national priority and we must allocate the necessary resources. We must also work to minimize the risks by reducing the carbon emissions that cause climate change.

Many of the United States' iconic landmarks and heritage sites are at risk as never before. Sea level rise, coastal erosion, increased flooding, heavy rains, and more frequent large wildfires are damaging archaeological resources, historic buildings and cultural landscapes across the nation. From sea to rising sea, a remarkable number of the places where American history was made are already under threat from the impacts of climate change. Here we summarize the findings of our groundbreaking new report—*National Landmarks at Risk: How Rising Seas, Floods and Wildfires are Threatening the United States' Most Cherished Historic Sites.*

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Hurricane Sandy's massive storm surge destroyed most of the radio equipment, electrical infrastructure, and security systems of both Liberty and Ellis Islands. Floodwaters inundated three-quarters of Liberty Island—some of the aftermath is pictured—and the beloved landmark was closed to the public for more than eight months.

Just the Tip of the Iceberg

National Landmarks at Risk is not a comprehensive analysis of climate change threats to all of the United States' historic places, monuments, and memorials, but rather a selection of case studies that vividly illustrate an urgent problem. These examples represent many of the rich and diverse elements of the American experience. The stories were chosen because the science behind the risks they face is robust, and because together they shine a spotlight on the different kinds of climate impacts already affecting the United States' cultural heritage.

All of the case studies in this report draw on observations of impacts that are either consistent with, or attributable to, human-induced climate change based on multiple lines of scientific evidence. Some of the sites face the risk of severe

damage or even eventual loss. Other case studies describe sites that are just now seeing the first signs of damage, or are experiencing disruptions to access and services that are likely to become worse, more frequent, or both. All provide a wake-up call: as the impacts of climate change continue, we must make hard choices now and take urgent steps to protect these sites and reduce the risks.

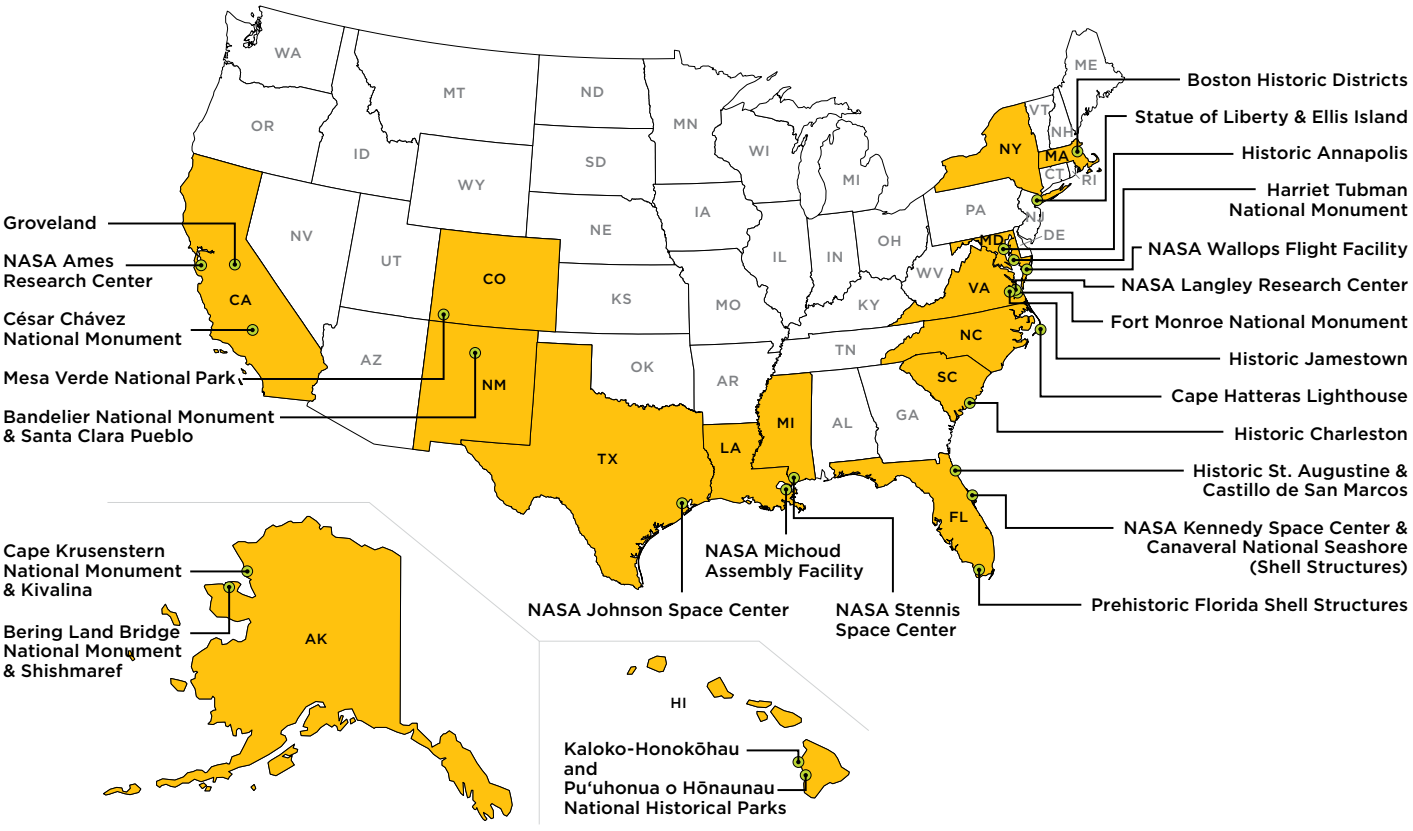
Case Study Summaries

Boston's historic Long Wharf, the Blackstone Block (a compact district of narrow, winding streets and alleys dating from the seventeenth century), and Faneuil Hall (a U.S. National Historic Landmark where Samuel Adams and other Sons of Liberty first met to plan the Boston Tea Party) are all at risk from rising seas. Ten of the 20 highest tides over the last hundred years have occurred in the last decade. The Organisation for Economic Co-operation and Development ranked Boston the eighth-highest metropolitan area worldwide in expected economic losses, estimated at $237 million per year, on average, between now and 2050, due to coastal flooding.

The **Statue of Liberty** still welcomes visitors and immigrants to the United States; 12 million immigrants arrived at **Ellis Island** between 1886 and 1924. Both landmarks were closed down in 2012 by Hurricane Sandy and its strong storm surge. The New York City area has seen a foot of sea level rise over the last century, which has contributed to the severity and extent of the flooding that occurred during the hurricane. Floodwaters inundated 75 percent of Liberty Island and almost all of Ellis Island, and millions of precious and irreplaceable artifacts were removed from the museum until repairs could be made. In its post-Sandy rebuilding efforts, the National Park Service elevated Liberty Island's electrical systems up to 20 feet above ground to avoid future storm surges, and flood-proofed heating and ventilating systems.

Climate change is threatening the **Harriet Tubman Underground Railroad National Monument** before it even opens. In March 2013, President Barack Obama set aside 480 acres on Maryland's Eastern Shore for the park, which is scheduled to open in 2015 to commemorate the life of the legendary abolitionist. The undeveloped marshes, fields, and forestland look

FIGURE 1. Map of Case Study Sites



Federal, state, and local officials broke ground for the new Harriet Tubman Underground Railroad National Monument, but because of local sea level rise at nearly twice the global average, the site could be largely under water by 2050.

much as they did in the nineteenth century when Tubman was born and grew up there, but the area's wetlands at sea level are being lost to the more rapidly rising ocean at the rate of about 300 acres a year.

Annapolis, Maryland's Colonial Historic District is home to the largest collection of eighteenth-century buildings in America, but already, the city experiences frequent nuisance flooding with high tides. The city is preparing for the inevitability of another major storm such as Hurricane Isabel, which caused severe flooding in 2003. By 2050, the city expects at least a doubling of high-tide flooding events. The adjacent U.S. Naval Academy, a national historic landmark, is also at risk: it sustained $120 million in damage from Hurricane Isabel.

At **Jamestown Island** in Virginia, the site of the first permanent English colony in what is now the United States, the threat from sea level rise is so strong that archaeologists are reconsidering their usual practice of leaving artifacts in the ground for future generations to discover, lest rising waters submerge them forever. By the end of this century, the only way to experience "America's birthplace" may be by reading about it in history books or online.

Fort Monroe is perched on low-lying Old Point Comfort at the mouth of Chesapeake Bay, where the first Africans became enslaved in English North America in 1619. Nearly 250 years later, General Benjamin Franklin Butler, the newly arrived commander at Fort Monroe, gave refuge to people escaping slavery on the basis that they were "contraband of war." The general's decision helped set off a chain of events that would ultimately lead to Congress passing the Thirteenth Amendment and abolishing slavery. Hurricane Isabel caused more than $100 million in damage to Fort Monroe's buildings and infrastructure. With rising seas, high tides and storms regularly flood basements and cause sewage from buildings on the island to flow into Chesapeake Bay.

Multiple **NASA sites** that have played a key role in the history of space exploration are at risk from sea level rise, storm surge, and stronger North Atlantic hurricanes. In Virginia, both the **Langley Research Center**, where breakthrough aeronautics and scientific research has been conducted, and **Wallops Flight Facility**, the site of more than 16,000 rocket launches, are affected. At the **Kennedy Space Center** in Florida, the site of Apollo and space shuttle missions, storm surges regularly breach the dunes near the launch pads. Together, the **John C.**

To help protect historic shops and buildings along the waterfront in downtown Annapolis, the city is developing a Cultural Resource Hazard Mitigation plan, which is likely to become a model for other historic coastal cities facing sea level rise, higher storm surges, and more frequent coastal flooding.

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At César E. Chávez National Monument, increasing heat waves and more frequent and prolonged periods of drought are threatening the health and livelihoods of farmworkers as well as California's $45 billion-a-year agricultural industry.

Stennis Space Center in Mississippi and the **Michoud Assembly Facility** in Louisiana experienced an estimated $760 million in damages from Hurricane Katrina. At the **Johnson Space Center** in Texas, home of the Apollo Mission Control Center, more than 160 buildings sustained damage from Hurricane Ike, while intense storms have closed facilities at the **Ames Research Center** in California.

© NASA

This building at Kennedy Space Center was almost totally unserviceable after losing approximately 35 percent of its roof to Hurricane Frances in 2004.

Because of the threat of shoreline erosion, the National Park Service moved the **Cape Hatteras Lighthouse**, America's tallest brick lighthouse, further inland at a cost of about $11 million. The lighthouse was a comfortable 1,500 feet from the ocean when constructed in 1870, but, in part due to sea level rise, wound up only 120 feet from the tideline before it was moved.

Parts of the Old and Historic District of **Charleston, SC**, a national landmark district that contains more than 4,800 historic structures, some dating back to the 1700s—are regularly flooded by summer thunderstorms. These impacts will become more severe and frequent in the coming decades, as global warming brings still higher sea levels and heavier rainfall events.

St. Augustine, FL, is the oldest city in the nation and home to the first port built in America, the country's earliest Catholic parish, and the oldest masonry fort in the continental United States. Sea level rise of three feet, which under a worst-case scenario could happen by around 2065 and under a medium- to high-emissions scenario is likely by the end of this century, could permanently inundate portions of the city's historic districts.

Florida's prehistoric shell structures. Rising seas and coastal erosion are endangering some of the most remarkable archaeological remains on Earth: the massive prehistoric oyster and clam shell structures on Florida's Gulf and Atlantic Coasts. Ten Thousand Islands, partially in Everglades National Park, is one of the only places in the world where coastal hunter-gatherers who lived primarily from the fruits of the sea built entire community complexes out of them. Another threatened structure, Turtle Mound, in the northern part of Canaveral National Seashore, is thought to be the highest in North America, and efforts are being made to protect it using living barriers made of oysters, spartina grass, and mangroves.

At **Mesa Verde National Park** in southwestern Colorado, Ancestral Puebloans built their homes on the high limestone and sandstone plateau. By the late eleventh century, they began moving into the sheltered alcoves of the canyon walls

© William Trinkle Photography

Sea level rise, worsening storm surges, erosion, and coastal flooding threaten landmarks in the nation's oldest city. Established in 1565 as a Spanish fort, St. Augustine, FL, was the seat of Spanish rule in North America for 200 years. The Castillo de San Marcos (left) is the oldest masonry fort in North America, and the only seventeenth-century fort that survives today.

beneath overhanging cliffs. Hotter and drier conditions have led to large and destructive, high-intensity fires and damaging floods in the park. Back-to-back fires in the summer of 2000 burned nearly half of Mesa Verde National Park's 52,000 acres. The Bircher Fire forced the evacuation of some 1,000 visitors because of the rapid spread of the flames toward the park entrance.

At **Bandelier National Monument** in New Mexico, the ancient rock carvings and cliff dwellings tell the story of some of the earliest inhabitants of the Americas. This landscape offers evidence of a human presence dating back more than 10,000 years while also serving as home to modern pueblo communities, such as the nearby Santa Clara Pueblo, that have an enduring sense of cultural identity. But major wildfires and severe flooding are now a major threat to the monument's archaeological resources and the neighboring pueblo.

The Gold Rush–era town of **Groveland, CA**, near Yosemite National Park witnessed the particularly destructive 2013 Rim Fire. It was the state's third-largest wildfire on record and overwhelmed the tight-knit community, destroying homes and closing businesses at the height of the tourist season. Climate change is increasing the risk of more frequent fires in California's Sierra Nevada Mountains by driving up temperatures and drying out forests for longer periods.

President Obama established the **César E. Chávez National Monument** in 2012 to honor the Latino labor leader, whose work on behalf of farmworkers led to higher wages and safer working conditions. The monument is located in the San Joaquin Valley, on the land where Chávez lived and organized what is now the United Farm Workers union. Now the valley is experiencing increasing heat waves and more frequent and prolonged periods of drought. These impacts are threatening the health and livelihoods of California farmworkers as well as the state's $45 billion-a-year agricultural industry.

Cape Krusenstern National Monument and the **Bering Land Bridge National Preserve** face each other across Kotzebue Sound in northwestern Alaska and both are losing irreplaceable archaeological remains to worsening coastal erosion. The parks contain some of the most important concentrations of archaeological sites and artifacts documenting the first human migration to North America via the Bering Land Bridge. Warming air and ocean temperatures have caused permafrost to thaw, as well as a reduction in the winter sea ice that used to protect the coast from erosion. The nearby native

© Shelby Anderson

As Alaska warms (on average by about 3°F over the last 60 years), protective winter sea ice is lost, permafrost thaws, and coastal erosion increases. Irreplaceable archaeological artifacts, like this biface spear point from Cape Krusenstern that dates to the Choris period (between 800 and 500 B.C.), are increasingly threatened.

Alaskan villages of **Kivalina** and **Shishmaref** are suffering major losses of coastal land, and both communities' residents have voted to leave their homes and relocate the settlements somewhere safer.

In the **Kaloko-Honokōhau National Historical Park** on the west coast of the Big Island, the ancient structures Hawaiians used to trap and raise fish for hundreds of years are vulnerable to sea level rise, as higher tides erode the walls and threaten to completely submerge them. In nearby **Pu'uhonua o Hōnaunau National Historical Park**, sacred sites, seawalls, fish traps, and ancient trails are likewise under threat from rising seas. The scenic backdrop to Pu'uhonua o Hōnaunau is Mauna Loa volcano, where the National Oceanic and Atmospheric Administration maintains an observatory that has been documenting atmospheric carbon dioxide levels since 1958.

The Science behind the Case Studies

Earth's global average surface temperature has risen since the late 1800s. Scientists are more certain than ever that since 1950 the warming has been largely due to human activities, mostly from the heat-trapping emissions produced by the burning of coal, oil, and gas to provide energy. The global average rate of warming is currently 0.7 degree Fahrenheit (°F) per century. Temperatures in the lower 48 of the United States are rising even faster, at 1.3°F per century.

This shift in temperature means that the risk of extreme heat is more likely, and because warmer air can also hold more water vapor, human-induced climate change has raised the overall water vapor content of our atmosphere. When storms occur, more rain or snow may fall compared with similar events decades ago in the same location.

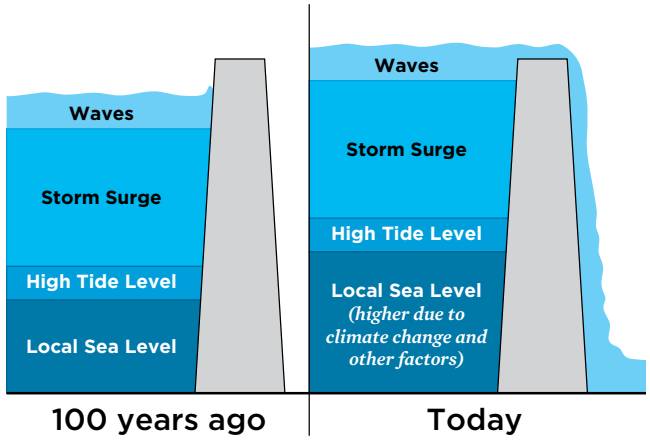
Rising Seas, Coastal Flooding, and Coastal Erosion

Since the end of the preindustrial period, human-induced climate change has increased temperatures such that nearly all measured glaciers are melting. Shrinking land ice, combined with expanding oceans (as a result of warmer water), increases the rate of sea level rise. Local land subsidence is also a factor. As a result, many coastal areas are likely to progressively become inundated; for example, sea level rise along the U.S. Gulf and East Coasts is among the highest in the world.

Coastal areas that are not permanently inundated can still experience occasional (episodic) flooding, resulting from the highest monthly or annual tides, or from strong winds. Coastal storms can pile water up and create a storm surge capped by waves. Moreover, with each passing decade, these episodic increases in storm surges will occur on top of sea levels that are rising more quickly, primarily because of climate change.

Coastal erosion can be accelerated when storms ride in on ever-higher seas. A severe example of an increase in such erosion is off the coast of Alaska, where the coastline is thick

FIGURE 2. Storm Surge on a Higher Sea



A hypothetical worst-case scenario for a storm surge 100 years ago compared with such an event today. Because the rate of sea level rise has increased as a result of human-induced climate change, this boost in elevation combined with naturally occurring factors can spell trouble during a storm surge. The shoreline protections in place, whether natural or engineered, could be overtopped.

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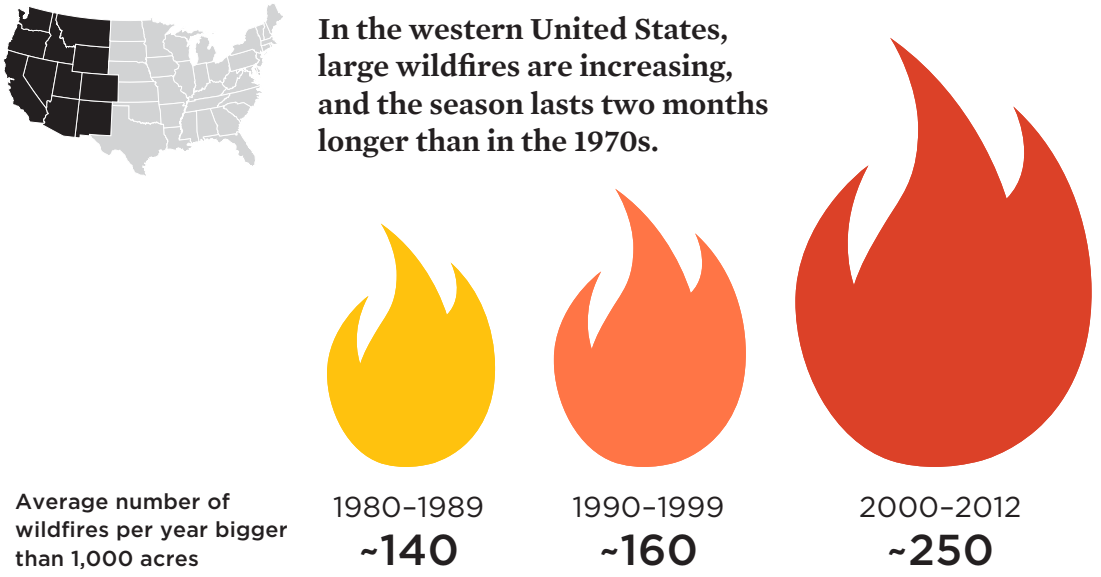
permafrost, comprised of frozen ice and soil. In the past, offshore sea ice prevented winds from making waves during the stormy season. But as climate change reduces the offshore sea ice, these coasts are feeling the full brunt of storm waves that in turn rapidly erode the permafrost, which in many places is thawing too.

Wildfires and Flash Floods

Warmer temperatures increase evaporation rates from surface water bodies. And they also reduce soil moisture, which in turn amplifies the risk of drought. This is especially true for places that already tend to be semi-arid. All else being equal, drier and hotter conditions add to the inherent risk of wildfires. In the western United States, as elsewhere, climate change has increased temperatures. One study reported that by 2002, snowmelt occurred one to four weeks earlier than it did in 1948. In regions where the earlier snowmelt and runoff are followed by a long, hot, and dry summer, the risk of large wildfires is elevated. In the western United States, the wildfire season—defined as the period from the first outbreak to the final control date of fires larger than 1,000 acres—has increased more than two months during the period from 1970 to 2012.

Typically, rain that falls on dry soils seeps in. Once the soil is saturated, additional rain will run off the surface and flow more rapidly downslope, adding to river flood risk. But after wildfires, landscapes are denuded, meaning that there remains little vegetation to take up rainwater. Further, the bare ground receives the full impact of rain, thereby further increasing the erosion potential from runoff. High heat from wildfires can also increase the rate of runoff by chemically altering the soil so that it repels water. All in all, the likelihood of flash floods increases substantially after wildfires in susceptible areas.

FIGURE 3. Changes in Wildfire Size and Season



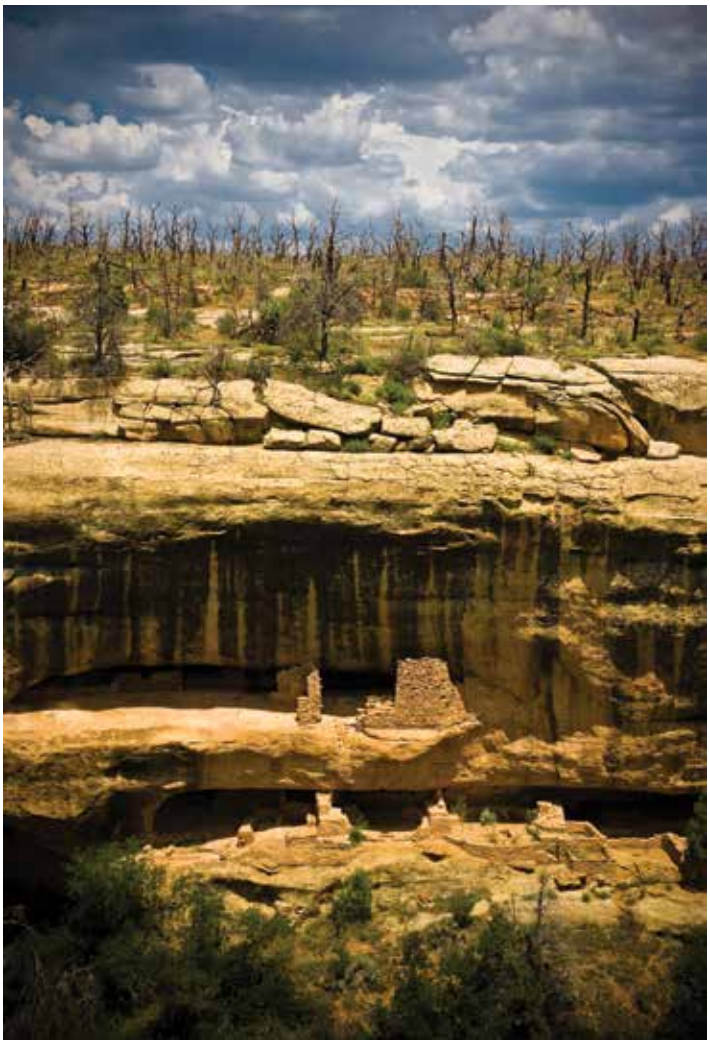
SOURCES: USGS 2013; WESTERLING ET AL. 2006.

A Call to Action

As *National Landmarks at Risk* illustrates, climate change is no longer a distant threat for others to worry about. The consequences are already under way, forcing federal and state agencies, park managers, archaeologists, historic preservationists, engineers, architects, and others to spend time and resources to protect sites today and prepare for expected additional changes tomorrow.

However, given the scale of the problem and the cultural value of the places at risk, it is not enough merely to plan for change and expect to adapt. We must begin now to prepare our threatened landmarks to face worsening climate impacts; climate resilience must become a national priority and we must allocate the necessary resources. We must also work to minimize the risks by reducing the carbon emissions that cause climate change. The science is clear that by abating our carbon pollution we can slow the pace of change and thereby lower the risks posed by extreme heat, flooding, and rising seas.

The United States boasts tens of thousands of national parks, landmarks, and historic places—many of them already affected by flooding, coastal erosion, wildfires, and other impacts.



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Mesa Verde National Park contains more than 4,500 archaeological sites, including 600 cliff dwellings. Back-to-back fires in 2000 caused extensive damage to park infrastructure—including roadway systems, visitor facilities, and watersheds—but spared the famous cliff dwellings.

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