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By John Ouellette

emergency declaration. An onslaught of potent storms brought heavy snow, torrential rain, and high winds, taking down power lines, eroding seawalls and beaches, washing out roads, damaging countless structures, and forcing hundreds of residents from their homes. The local news story of the year was the series of prolonged and widespread power outages that followed major storms. Throughout the year, cities and towns faced the tasks of evacuations, removing debris, and repairing infrastructure and municipal buildings.

One bad year certainly does not constitute a trend. But could 2011 be a harbinger of what's to come? Climate scientists warn that "extreme weather events" are increasing in frequency, and will continue to do so. Rain storms are becoming heavier, ocean storm surges are getting higher, tropical storms are becoming more powerful, flooding is becoming more common, and the proverbial hundred-year storm is occurring much more frequently than its name would suggest.

This emerging climate reality presents a growing challenge for local officials, who are typically on the front lines of emergency response. Cities and towns are likely to face an ever-increasing demand for services such as emergency management, evacuation and sheltering, snow and debris removal, repairs to road, bridge and water systems, and response to coastal flooding and erosion. Municipalities are now being urged to take climate change into account in their emergency planning efforts and to reassess policies—regarding land use, for example—in order to lessen the impacts of severe weather. Local bylaws and emergency plans, built on past experience and obsolete assumptions and data, need to be brought up-to-date and account for expected future conditions.

"Effective emergency response systems will be critical in preparing for climate change impacts and extreme weather events," states the *Massachusetts Climate Change Adaptation Report*, published last September by the Executive Office of Energy and Environmental Affairs. "As storms become more frequent and intense and sea level rises, new and increased levels of exposure may arise, and many areas that previously escaped storm impacts will likely be vulnerable. ... Planning for and managing impacts of climate change before they occur are preferable to reactive decision-making after an impact takes place."

The Changing Climate

Setting aside any debate about its causes—or how to slow it down—there's ample evidence that the world's climate is indeed changing. The indicators, according to the U.S. Global Change Research Program, include documented increases in global average air and ocean temperatures, widespread melting of glaciers and polar ice, and a rising global average sea level. Over the past century, the average temperature of the Earth's surface has increased by 1.4 degrees Fahrenheit, according to the National Research Council, but two-thirds of this increase has occurred in just the past three decades. Worldwide, 2000-2009 was the warmest decade on record. The warming is not distributed evenly, however. In the Northeast, the annual average temperature has increased by 2 degrees Fahrenheit since 1970, with winter temperatures rising twice this much, according to the Global Change Research Program. Sea surface temperatures here have increased by 2.5 degrees since 1970.

Increases of a couple of degrees may not sound like much, but they are significant enough to upset the delicate balance of the world's complex weather systems. Take precipitation, for example. Even slightly warmer sea and land temperatures cause an increase in evaporation, which, ultimately, means more precipitation. Warmer air also holds more water vapor, which results in more frequent heavy rainfall events. And rising temperatures mean that a larger proportion of precipitation falls as rain rather than snow.

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HIGHER SEAS, FIERCER STORMS CREATE CHALLENGES FOR CITIES AND TOWNS

Climate Change Indicators in the United States, a report published last year by the U.S. Environmental Protection Agency, finds that annual precipitation has increased by between 10 percent and 20 percent in New England over the past century. But the higher volume isn't coming in soft, steady showers. "In recent years, a higher percentage of precipitation in the United States has come in the form of intense, single-day events," the report states. "Eight of the top ten years for extreme one-day precipitation events have occurred since 1990. The occurrence of abnormally high annual precipitation totals has also increased."

According to the Global Change Research Program's 2009 report *Global Climate Change Impacts in the U.S.*, the Northeast is experiencing the following changes:

- More frequent very hot days
- A longer growing season
- An increase in heavy downpours
- Less winter precipitation falling as snow and more as rain
- · Reduced snowpack
- Earlier break-up of winter ice on lakes and rivers
- Earlier spring snowmelt resulting in earlier peak river flows
- Rising sea surface temperatures
- A rising sea level

Tropical storms are also becoming more of a threat. Six of the ten most active hurricane seasons have occurred since the mid-1990s, according to the EPA, an increase that is closely related to changes in sea surface temperature in the tropical Atlantic.

These climate trends are expected to continue, and are likely to accelerate, according to the Intergovernmental Panel on Climate Change, a scientific body that advises the United Nations. In Massachusetts, we can expect an increase in air temperature of 5 to 10 degrees Fahrenheit by the end of this century, with temperatures hitting 100 degrees a projected twenty-eight times a year. The EPA's climate

2011 Weather Emergencies in Massachusetts

January 11–12: Blizzard

A Nor'easter dumped more than two feet of snow across most of the state, accompanied by wind gusts as high as 65 mph, according to the National Weather Service. It followed a previous major snowstorm by just two weeks.

Result: Fallen trees, widespread power outages, collapse of roofs

Federal Major Disaster Declaration

This storm is ranked number eighteen on the list of highestimpact snowstorms in the Northeast since 1956, according to the National Oceanic and Atmospheric Administration.

June 1: Tornado

Six tornados struck eleven communities in Hampden and Worcester Counties. (See related stories, pages 10–14.)

Result: Widespread destruction of structures and trees, massive quantities of structural and natural debris, hundreds left homeless

Fatalities: 3

Federal Major Disaster Declaration

Spawned from powerful thunderstorms, tornados are nature's most violent storms, with whirling winds that can reach 300 mph. Statistically, Massachusetts has about the same frequency of tornados as Texas or Missouri, 1.1 tornados per 10,000 square miles, according to Springfield Emergency Preparedness Director Robert Hassett. A tornado that struck the Worcester area in 1953, causing ninety-four deaths, is the nation's second-deadliest of the past sixty years, following the 159 people killed by a twister that tore through Joplin, Missouri, in May.

August 28: Tropical Storm Irene

Hurricane Irene was downgraded to a tropical storm shortly before striking Massachusetts, but it was still a powerhouse. Due to torrential rainfall, the Westfield River rose almost twenty feet in a matter of hours; the Deerfield River rose more than fifteen feet in the same period.

Result: Torrential rain, substantial flooding, particularly in the western part of the state, widespread power outages, evacuations, destruction of roads and bridges

Fatalities: 1

Federal Major Disaster Declaration

October 29–30: Pre-season snowstorm

This major snowstorm struck before most trees had lost their leaves, causing branches to catch more of the snowfall and then snap from the weight, taking down numerous power lines. Wet, heavy snowfall reached thirty inches in parts of Berkshire County, and winds topped out at 70 mph.

Result: Extended power losses for hundreds of thousands of residents and businesses, loss of countless trees

Fatalities: 6

Federal Emergency Declaration

– John Ouellette

change report concludes that "extreme weather events such as storms, floods, and hurricanes will likely become more intense." We are likely to see a marked increase in weather volatility and intensity, with a growing frequency of unseasonable events, such as a blizzard in October or a 60-degree day in January.

Nationwide, more than 3,000 monthly weather records were broken in 2011, according to the Natural Resources Defense Council, with record-breaking eventsrecord temperatures, record rainfall, record snowfall, widespread flooding, drought, or wildfires-in each of the fifty states. Massachusetts experienced all of these events except for droughts and wildfires.

These developments are not lost on the insurance industry, which has seen a significant increase in property damage claims resulting from severe weather. The Geneva Association, a nonprofit group comprising eighty chief executive officers from the world's largest insurance companies, has identified climate change as the industry's top long-term priority. "There is evidence that changing patterns of extreme events are drivers of recent increases in global losses," the association wrote in its 2009 report, The Insurance Industry and Climate Change. "[O]verall, the costs of weatherrelated claims, in particular from flood and drought and in some regions also from wind and fire, can be expected to rise."

Washed Away

Increasing storm intensity and rising seas have been making their presence felt for years in the state's seventy-eight coastal communities, where the ocean has consumed thousands of acres of prime real estate, toppled seawalls, flooded basements, and washed houses out to sea. The rising tide has been changing the landscape before our eyes. "The sea has encroached," says Patricia Vinchesi, town administrator in the South Shore town of Scituate. "If vou look at pictures from thirty or forty years ago, and you see our beaches, and you see what's left for beaches now, there's almost nothing left in a lot of cases." In an interview with the Boston Globe last April, Scituate Selectman Rick Murray, an earth science professor at Boston University, said simply, "We are fighting a losing battle with the sea."

Tide gauge readings show that the sea rose by roughly a foot in Massachusetts



during the twentieth century. The rate, however, has been increasing in recent decades, and scientists predict a rise of at least two to three feet-and possibly as much as six-by the end of this century. The problem is compounded by changes in ocean circulation patterns, "thermal expansion" (water's volume grows as it warms), and a slow settling of the landmass in the Northeast. Couple this with fiercer storms, and water is pounding structures and swamping land like never before.

Sea-level rise isn't just an issue for communities with ocean views. Ocean storm surges-elevated further by sea-level risecan push back at rivers that ordinarily drain into the sea. "When we have these extreme rain events ... and then we also have an extreme tide coupled with that, the tidal level is reaching further up the river," says Julia Knisel, coastal shoreline and floodplain manager with the Massachusetts Office of Coastal Zone Management. "And then rain doesn't really have anywhere to go, so it's definitely backing up into communities."

The EPA's climate change report predicts that "severe flooding due to sealevel rise and heavy downpours is likely to occur more frequently" in coming years. "The densely populated coasts of the Northeast face substantial increases in the extent and frequency of storm surge, coastal flooding, erosion, property damage, and loss of wetlands." To put the risk in perspective, the Massachusetts Climate Change Adaptation Report estimates that a two-foot rise in sea level by 2050 could damage assets worth an estimated \$463 billion in Boston alone.

The aptly nicknamed Bay State has more than 1,700 miles of coastline, about

8 percent of which is protected by seawalls, jetties, bulkheads and other barriers, according to the Department of Conservation and Recreation, which published a comprehensive inventory of publicly owned coastal protection structures in 2009. These structures tend to be found in densely developed areas, where they shield billions of dollars of coastal property, commercial operations and infrastructure as well as valuable public recreation areas. One startling finding in the DCR report is that 85 percent of these structures are beyond their expected lifespan of fifty years and have never seen major repairs. "It is feared that without rehabilitation of these structures," the report warns, "a storm equivalent to the Blizzard of 1978 or Hurricane Bob [in 1991] will cause incalculable damage to the coastline and upland areas of the Commonwealth."

The problem, of course, is money. Rebuilding seawalls and other barriers is very expensive, and there's little funding available. When a seawall collapses, the Federal Emergency Management Agency may reimburse 75 percent of the cost to rebuild, but the agency only pays for the portion that was destroyed, which could be just twenty feet out of three hundred, leaving the remainder vulnerable. Some communities have a capital plan to maintain the structures, but given the cost involved, they simply can't keep all the seawalls in suitable condition. The Union of Concerned Scientists pegs the cost of building a seawall at between \$5 million and \$21 million per mile. The DCR report estimates that it would cost \$627 million to restore the 140 miles of

publicly owned coastal protection structures in Massachusetts to their original condition. Three-quarters of this inventory is the responsibility of cities and towns.

Barry Keppard, a regional planner with the Metropolitan Area Planning Council, recently completed an extensive coastal hazards report for the communities of Duxbury, Marshfield and Scituate, all of which have seen seawalls collapse. In the face of rising seas, he says, communities essentially have three options, each with a substantial downside: protect (costly), accommodate (also costly), or retreat (disruptive and likely unpopular).

"Protection means that you're going to decide to fight back against what's coming at you and rebuild stronger, or higher," says Keppard. Accommodation "is a way of understanding that the water is going to be doing something different than it did in the past, and how do you work with it as opposed to just buttressing against it." This might mean moving buildings, roads and other infrastructure that are in harm's way, elevating homes, and using higher-volume culverts-actions that will allow water to flow. Retreat means "telling someone whose home got destroyed that they can't rebuild there." It may sound harsh, but in some cases it's the best solution. Keppard says local officials would likely pursue a combination of all three options, in degrees that reflect the values of the community. "There isn't a silver bullet," he says.

Local Response

At the local level, climate change has largely been a conversation among environmental activists, who tend to focus on mitigation-efforts to reduce greenhouse gas emissions. Local officials, meanwhile, and the agencies enlisted to assist them, tend to avoid the broad, politically thorny issue and zero in on documented effects. "At the end of the day," says Vinchesi, succinctly, "it's the seawall problem." The MAPC, Keppard says, has been following the lead of colleagues from Maine who are also assisting communities with risks related to the rising sea. "It doesn't matter what's causing it," Keppard says. "We used known quantities: tide gauges, storms. ... We can clearly see that there's a new kind of state that we're going to exist in, and that there are natural hazards that are associated with that.

"Climate change," he acknowledges, "is definitely one of those issues that's like the center of a spider web. When you pull on it, you pull on pretty much everything. That's why I think it's a very daunting thing, because you're not necessarily responding to just one element of it. ... It has the tremendous potential to touch on a lot of different things."

Massachusetts Precedence for 'No-Build' in Dangerous Coastal Areas

hen a landowner sued the town of Chatham for its refusal to permit construction of a new home in the town's mapped floodplain, Chatham defended its floodplain zoning bylaw, intended to protect local people, property and resources. In 2005, the Massachusetts Supreme Judicial Court issued a landmark ruling that upheld the bylaw, citing reasonable public interest, stating that its enforcement was not tantamount to a taking and did not require direct compensation from the town. Further, the land retained more than a token value. Even though residential units could not be built on the land, various other uses, including fishing and agricultural uses, were allowed on the site. The town's right to enact regulations that ensure the safety of its citizens in the face of a hazardous landscape was upheld.

- Reprinted from Massachusetts Climate Change Adaptation Report, September 2011

There's a clear divide on the issue between coastal areas and inland ones. Along the coast, observers say, the tide, so to speak, is beginning to turn.

"What's happening is that towns are now in the second and third iteration of repairing seawalls or putting up berms along beaches, and then they just get blown away again a couple years later," says Sam Cleaves, a senior planner with the MAPC who convenes a task force of fifteen North Shore communities to discuss the impacts of climate change. "So towns are beginning to ask, what are the longerterm implications of what's going on? They're looking for better planning tools, and more information.

"We certainly won't be dropping this," he adds. "It's becoming a much bigger topic."

Some communities are making efforts to address sea-level rise. Duxbury, Marshfield and Scituate initiated their coastal hazards study as a basis for assessing their options for mitigating flood emergencies. Scituate now requires that a one-foot sealevel rise be taken into account for all activities in the coastal floodplain. In Boston, larger projects must consider climate change in their construction planning. Chatham has a zoning bylawupheld by the Supreme Judicial Court in 2005-that designates "conservancy districts" encompassing all land in the town's 100-year floodplain; the bylaw virtually bans new construction in the flood zone.

Quincy and Scituate have been helping the owners of flood-prone homes to tap FEMA funds to elevate their dwellings, or at least to get utilities out of harm's way. In Quincy, where the maximum award is \$20,000 per property, nearly \$1 million in federal funds was used between 2003 and 2007 to reduce storm damage risks at forty-six properties. In Scituate, fifty homes were elevated between 2006 and 2008, with FEMA picking up three-quarters of the tab. Quincy, one of thirteen Massachusetts communities participating in FEMA's Community Rating System program, has earned a 15 percent discount in federal flood insurance premiums for property owners as a result of its local flood mitigation efforts. In Scituate, also a CRS participant, the discount is 10 percent.

The town of Hull, a peninsula with twenty-seven miles of coastline, launched a program in 2009 that provides an incentive to owners of waterfront property to raise the elevation of new construction by at least two feet above what is required by state and federal flood zone rules. Qualifying owners get a discount of up to \$500 on building permit fees. The program has been cited as a "Best Practice" by FEMA and received an "Excellence in Local Government" award from the National Oceanic and Atmospheric Administration. A statement from the Hull Conservation Department says the program was developed "in the interests of protecting the health and safety of Hull citizens, preventing property damage, and reducing the need for costly emergency services during storm events."

Climate change is a central feature of a model coastal floodplain development bylaw developed by the Cape Cod Commission for use by the fifteen Cape communities. "Most building codes and other design standards have only one opportunity to minimize risk of future hazard damage: at the time of initial permitting and initial construction," states the report that accompanies the bylaw. "The probability of a coastal hazard affecting a building in the future should be factored into the location and elevation of any structure built in the coastal floodplain. This requires knowing the erosion rate and relative sea-level rise rate at the site and factoring the 'probability' of erosion and/ or elevated flood and surge waters affecting the building for the life expectancy of the structure." The report notes that FEMA encourages stricter floodplain development standards than those of the National Flood Insurance Program-and that FEMA indicates that more restrictive local codes would take precedence. It also notes that the Association of State Floodplain Managers advises state and local governments to use land-use planning and management techniques to guide development away from hazardous or sensitive coastal areas.

While the model bylaw has yet to be adopted by a Cape community, its coauthor, Jim O'Connell, managed to get it implemented in Scituate, where he is the conservation agent. A coastal management specialist, O'Connell is among the voices urging communities to be proactive in reducing exposure to climate-related emergencies. Along the coast, he suggests requiring higher elevations for reconstructed dwellings in floodplains and

"possibly limiting sensitive development in areas that may be impacted by anticipated higher wave elevations, higher flooding elevations, and areas that today may not be flooded, but will be in the future."

Angus Jennings, vice president of the Massachusetts Association of Planning Directors, laments the "disconnect" between emergency management planning and land-use planning in communities statewide. But, he quickly adds, local planning departments are overwhelmed by day-to-day responsibilities such as permitting, inspections, enforcement, and other duties-not to mention a stream of unfunded mandates. "It's kind of a joke to operate under the illusion that any community, with the exception of Boston and perhaps a few others, has dedicated staff resources to do hazard mitigation planning," he says. "There's a structural deficit in planning. We do not have the staff to do what needs to be done."

Jennings, currently the director of land use management in Westford and formerly the town planner in Marshfield, says perpetually strained municipal budgets result in "governing by crisis," where resources are allocated when a problem becomes so severe that it outweighs other competing needs. He says leadershipand resources-on this issue are sorely needed from higher levels of government. Unfortunately, he points out, "the federal disaster policy in fact subsidizes development in hazardous locations, particularly through the National Flood Insurance Program." He says it's time for the federal government to help, not hinder, local hazard mitigation efforts.

Updates Needed

A lot of work remains to ensure that local efforts are based on the latest available information and conditions, and that they take into account the coming impacts of climate change. The Massachusetts Climate Change Adaptation Report points out that much of the information and products currently used for land-use, infrastructure and emergency planning "reflect climate conditions from the last several decades and do not accurately reflect current risks of inundation, temperature change, and other climate-related impacts." Federal flood insurance maps and reports are notoriously out-of-date, often continued on page 35



The Myth of the levast **100-Year Storm**

he concept of the 100-year storm figures prominently in emergency planning. But many government agencies are now backing away from the term, because it implies a massive storm that comes only once every 100 years, or a storm that is 100 years off. Some take the term to mean that after surviving a major storm, you don't have to worry about another similar event for another 100 years.

In actuality, explains Julia Knisel of the Massachusetts Office of Coastal Zone Management, "a 100-year storm refers to a storm of a certain magnitudethat has a 1 percent chance of occurring in any given year."

When you incorporate the effects of climate change, however, "that factor becomes more like 5 percent or 10 percent."

"Because of sea-level rise, a storm with a certain surge will have a greater reach within a community, so you'll see greater impacts more frequently," she says. "So that does increase the frequency number for that particular magnitude of event."

To put this back in the 100-year context, what used to be considered a 100-year storm will soon become a twenty-year storm, and then a ten-vear storm.

-John Ouellette

HIGHER SEAS, FIERCER STORMS CREATE CHALLENGES FOR CITIES AND TOWNS

continued from page 27

going decades without a thorough update. Equations used by state and local governments to estimate flood impacts rely on rainfall data that haven't been updated in at least thirty-five years, and they often fail to capture the effects of recent development and impervious surfaces that change water flow. The data used to support the design of bridges and culverts—structures that are meant to allow stormwater to flow without damaging roads and buildings—are more than half a century old.

"We have the dubious distinction of having the oldest set of [stormwater] assumptions in the nation," says Nat Karns, executive director of the Berkshire Regional Planning Commission. "That means that every storm system being designed in the Commonwealth, even as we speak, is probably being under-designed.... We're seeing on the ground now some of the ramifications of having all of these systems undersized." Due to a spike in washed-out roads, the Berkshire commission is mounting a major initiative to get the culvert design assumptions in Massachusetts brought up-to-date.

Communities are responsible for re-examining and updating their own comprehensive emergency plans on a regular basis. Issues such as the location of evacuation routes, emergency shelters, muster points, and key infrastructure and equipment should all get another look in light of the new climate reality, experts say. Are drinking water and wastewater facilities vulnerable to higher potential flooding levels? How about solid and hazardous waste facilities? In the wake of a localized disaster, some communities have discovered that they weren't adequately prepared for the outpouring of volunteers and donations, the stream of gawkers, and the management of debris. On any of these issues, it's best to have a plan in place. A continuity of operations plan is also recommended (see related story, this issue).

Communities could use some help, though, with the underlying assumptions. Updated flood zone maps would be a good start. On this front, the Office of Coastal Zone Management is stepping in—at least for coastal communities. New, precise elevation data, gathered using airborne laser sensor technology known as LiDAR, will be made available to communities by the end of this year, according to Knisel at CZM. The data, accurate to within six inches, can be used to help predict the impact of flooding and sea-level rise and to identify neighborhoods, businesses, and infrastructure that are at risk. "When an emergency manager is looking at current evacuation routes, they can look at how sea-level rise with a storm event might interfere with what they have mapped out," Knisel says. "They might also want to look at what facilities they're using for emergency shelters and make sure that individuals will have access to those buildings during an event and that the buildings won't be compromised. ... There are a number of local planning and review committees that could definitely take this information into account." The LiDAR data will be fed into the state's MassGIS system.

Knisel says CZM's StormSmart Coasts program (www.mass.gov/czm/stormsmart) is available to help communities deal with challenges arising from storms, floods, sea-level rise, and climate change. The website provides resources for hazard identification and mapping, planning, regulations development, and protecting infrastructure, among other coastal floodplain management issues. CZM also holds workshops to help communities incorporate sea-level rise into local bylaws and planning efforts.

For local leaders who feel overwhelmed by the prospect of adding climate change to their list, Keppard reminds them that they can start with modifying work they've already done. "Instead of thinking that we have this problem and we have to come up with all these new solutions," he says, "it's knowing that we can probably adapt what we already have."

The Massachusetts Climate Change Adaptation Report acknowledges that "challenging decisions lie ahead" for communities regarding the options for reducing risk to public infrastructure, private property, and human safety and welfare as a result of climate change. It recommends, however, that these challenges not be put off any longer. "Like many issues," says Keppard, "where the rubber meets the road will be at the local level. People think of it as a global issue, but the effects will be felt locally."