

# Encroaching Tides

## *How Sea Level Rise and Tidal Flooding Threaten U.S. East and Gulf Coast Communities over the Next 30 Years*

### **HIGHLIGHTS**

*Sea level rise is visible today in communities up and down our coasts in the form of increased tidal flooding. Given the accelerating rate at which sea levels are rising, the reach of the tides is poised to grow substantially. Our analysis explores projected changes in tidal flooding under a mid-range scenario of sea level rise, and the implications for East and Gulf Coast communities in the absence of adaptive measures.*

*Over the next 15 to 30 years, the frequency, extent, and duration of tidal flooding could increase substantially in many of the 52 locations examined, and tidal flooding is poised to expand in this time frame to communities that at present are largely unaffected by it.*

*We need commitments from local, state, and federal officials that will help us adapt to rising seas, and help slow the rate of sea level rise by reducing global warming emissions.*

Today scores of coastal communities in the United States are seeing more frequent tidal flooding. And as global warming drives sea levels higher over the next 15 to 30 years, flooding from high tides is expected to occur even more often and cause more disruption, particularly on the East Coast and, increasingly, on the Gulf Coast. This flooding will redefine how and where people in affected areas live, work, and otherwise go about their daily lives. Coastal communities, and the nation as a whole, need to start planning today to cope with sea level rise and unprecedented tidal flooding, and to take swift and decisive action to limit longer-term damage to our coasts.

### **A Daily Cycle Gains Disruptive Force**

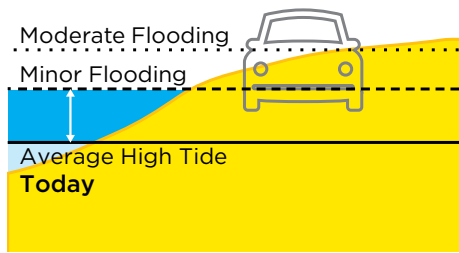
High tides are having a greater impact on U.S. communities today than in decades past for two reasons. First, our shores are more heavily developed, so higher tides affect more people and infrastructure. Second, these tides are now occurring on top of elevated—and rising—sea levels.

Global sea level rose roughly eight inches from 1880 to 2009. That rise occurred because global warming accelerated the melting of land-based ice into the oceans, and because seawater expanded as it absorbed heat from a warming atmosphere. Sea level rise is accelerating globally today, and at especially fast rates along parts of the East Coast.



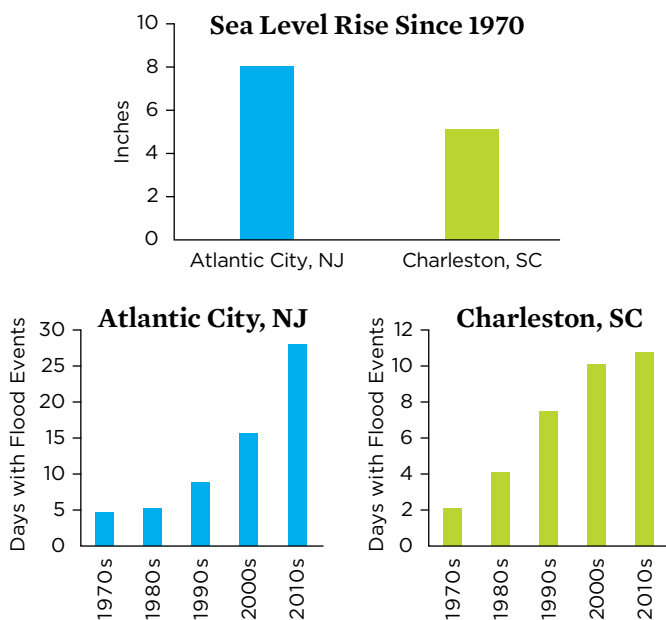
Annapolis, MD, in December 2012, when wind, rain, and high tides combined to cause disruptive flooding.

FIGURE 1. Identifying Flooding Thresholds



Tidal flooding can occur when high tide exceeds the normal level by about one to three feet (white arrow), depending on the location. Minor, or nuisance, flooding, as determined by the National Weather Service, can disrupt local transportation and daily life. Moderate flooding is more extensive and can threaten life and property. This type of flooding can occur with an extreme high tide, or when high tide combines with a storm system. As sea levels continue to rise, tides will exceed these thresholds more often.

FIGURE 2. Local Sea Level Rise and Tidal Flooding, 1970–2012



Sea level has risen by about 3.5 inches globally—but more along the East Coast—since 1970. Rising seas mean that communities up and down the East and Gulf Coasts are seeing more days with tidal flooding. Charleston, SC, for example, faced just two to three days with tidal flooding a year in the 1970s. The city now averages 10 or more such days annually.

SOURCES: UCS ANALYSIS; MORALES AND ALSHEIMER 2014; NOAA TIDES AND CURRENTS 2014; NOAA TIDES AND CURRENTS 2013B.

Coastal communities are all too familiar with the catastrophic damage that can result from major storms, storm surge, and flooding, but they have historically seen high tides as routine. Some tides periodically rise higher than the daily average because of the gravitational pull of the moon and sun. Flooding can result, but that has until recent years been infrequent. Today, however, as the reach and effect of the tides is changing as sea levels rise, our thinking about how we live with the tides—indeed, how we live near the sea—must change, too.

### COASTAL COMMUNITIES ON THE FRONT LINE OF TIDAL FLOODING

To analyze how often flooding now occurs at locations along the East and Gulf Coasts—and the frequency and extent of flooding that communities along these coasts can expect, on average, 15 and 30 years from now—we relied on 52 tide gauges from Portland, ME, to Freeport, TX. We limited our analysis to locations where flooding thresholds, defined at the gauges, correlate well with coastal flood advisories issued by the National Weather Service.

Our analysis shows that many East Coast communities now see dozens of tidal floods each year. Some of these communities have seen a fourfold increase in the annual number of days with tidal flooding since 1970.

When tidal floods occur, water can cover coastal roads for hours, making passage risky or impossible. With water on the street, some residents can be effectively trapped in their homes, and homes can be damaged. Entire neighborhoods can be affected, even isolated. In many communities, retail stores, restaurants, other businesses, and public infrastructure are clustered in low-lying waterfront areas, in easy reach of tidal flooding.

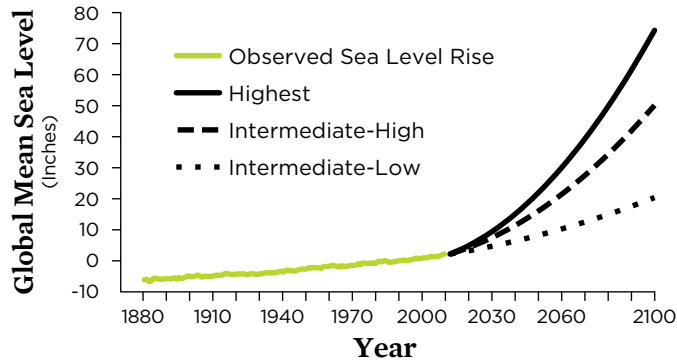
### Tidal Flooding in the Next 15 to 30 Years: Frequent, Disruptive, Widespread

#### AN OCCASIONAL EVENT BECOMES CHRONIC, THEN INCESSANT

Using a mid-range scenario for future sea level rise, we find that, by 2030, more than half of the 52 communities we analyzed on the East and Gulf Coasts can expect to average more than two dozen tidal floods per year. The rise in the frequency of tidal flooding by 2030 represents an extremely steep increase for some, and two-thirds could see a tripling or more in the number of high-tide floods each year.

The mid-Atlantic coast is expected to see some of the greatest increases in flood frequency. Because many

FIGURE 3. Historical and Projected Sea Level Rise



The 2014 National Climate Assessment used several different assumptions about how oceans and land-based ice will respond to future warming to project global sea level rise. We based projections for sea level rise at our 52 locations on the assessment's intermediate-high scenario, which factors in moderate rates of ice sheet loss.

SOURCES: CLIMATE CENTRAL N.D.; WALSH ET AL. 2014; PARRIS ET AL. 2012.

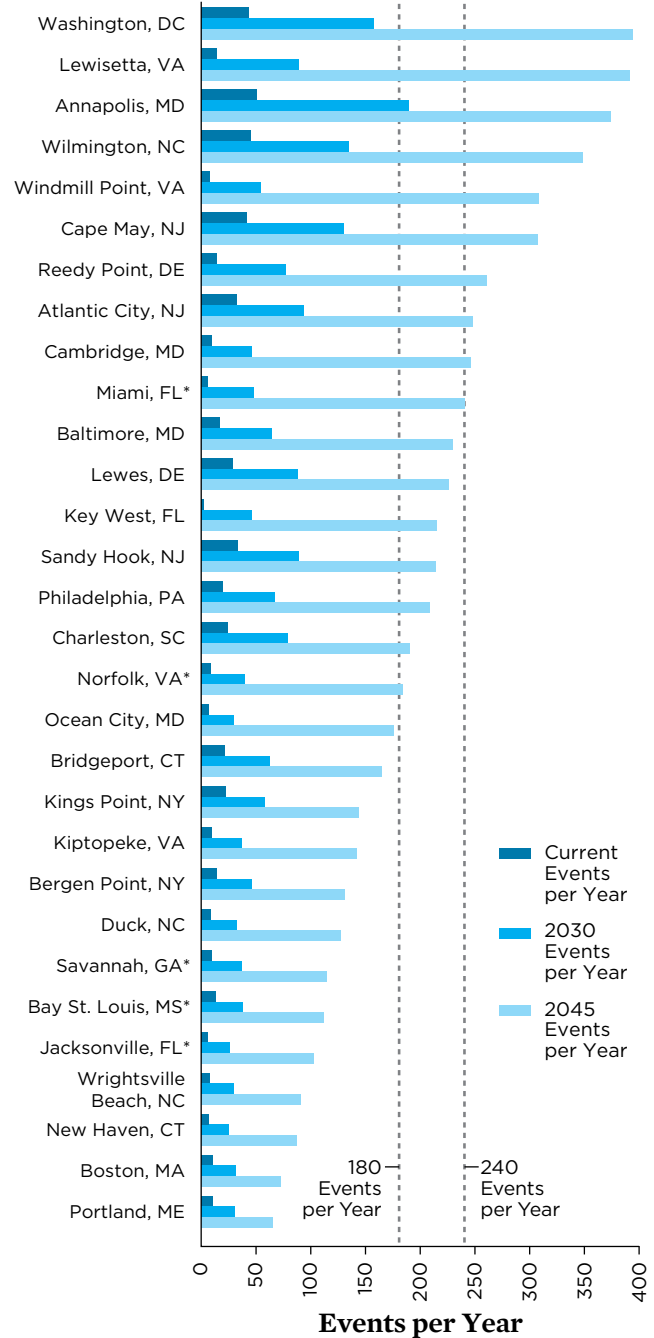
communities are already coping with tidal floods, a tripling in their frequency means that, by 2030, such floods could occur more than once a week. Places such as Annapolis, MD, and Washington, DC, for example, can expect more than 150 tidal floods a year, on average, and several locations in New Jersey could see 80 tidal floods or more.

By 2045—within the lifetime of a 30-year mortgage—many coastal communities are expected to see roughly one foot of sea level rise. As that occurs, one-third of the 52 locations in our analysis would start to face tidal flooding more than 180 times a year, on average. And nine locations,



In Norfolk, VA, tide gates are deployed to keep floodwaters out of the downtown and maintain business as usual. But by disrupting daily life often enough, tides alone can make business as usual in some parts of communities impractical, if not impossible.

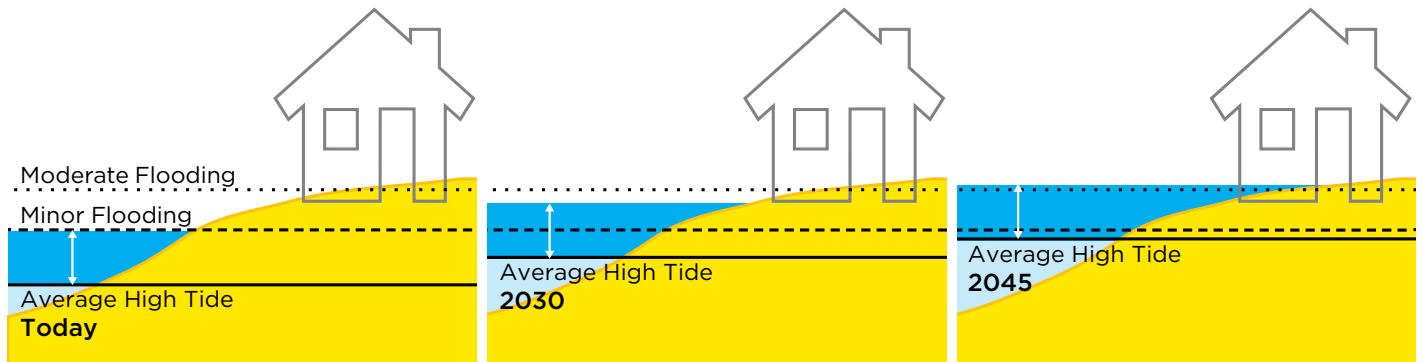
FIGURE 4. Tidal Flooding Today, in 2030, and in 2045



Of the 52 locations we examined, 30 (shown here) can expect at least two dozen tidal floods per year, on average, by 2030, and some of those can expect much more. (Note that some communities, such as Broad Channel in Jamaica Bay, NY, see roughly this much flooding today; however, this flooding is not captured by the closest tide gauge.) By 2045, one-third of the locations we analyzed can expect 180 or more tidal floods, on average, per year (15 per month). And nine locations could average 240 or more tidal floods a year by 2045 (20 per month).

\* Data for these locations are represented by nearby tide gauges; see the appendix for tide gauge locations.

FIGURE 5. The Growing Reach of Tidal Flooding as Thresholds Are Exceeded More Often



A tide that causes a minor flood today is a nuisance (white arrow). In the future, higher sea levels will allow high tides to push water deeper into coastal communities, affecting more homes, businesses, and infrastructure. Extensive moderate flooding—now usually associated with storms and high winds—is expected to become more common, simply from high tides.

**In the next 15 years, two-thirds of these communities could see a tripling or more in the number of high-tide floods each year.**

including Atlantic City and Cape May, NJ, can expect to see tidal flooding 240 times or more per year.

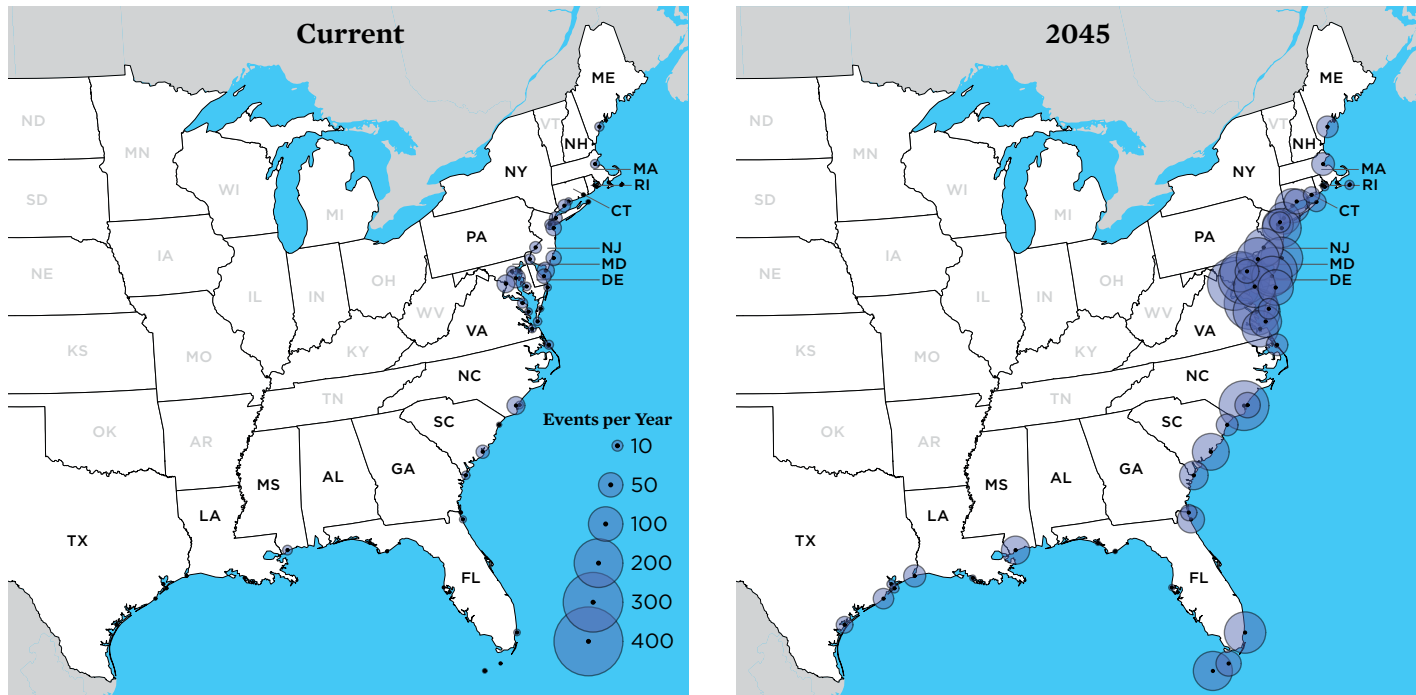
In this future, days without high-tide floods could start to become the exception in certain places. Without sensible preparation for these disruptions, conducting daily life in such flood-prone areas would become, at best, unreliable and, at worst, dangerous.



Today's tidal flooding might persist for a couple of hours as the tide peaks and ebbs, as it did here in Carolina Beach, NC. In the near future, as sea level rises, high tides will be able to reach farther into communities, creating flood conditions that last longer and disrupt business as usual for growing numbers of people.

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FIGURE 6. The Growing Frequency and Spread of Tidal Flooding



Relatively few of the 52 locations we analyzed on the East and Gulf Coasts now face minor or moderate tidal flooding on a regular basis (left; circle size represents the number of flood events). But by 2045, sea level rise will bring more tidal floods to nearly every location. By 2045, many communities can expect a 10-fold increase in the frequency of tidal floods (right). Only five of our locations would average fewer than five a year.

#### FLOODING DURING HIGH TIDES BECOMES MORE EXTREME

Today strong winds or a storm system are typically required for coastal flooding to become extensive. But sea level rise is changing that. In the near future, higher seas will mean that high tides can reach farther inland, creating flood conditions that last longer and disrupt daily life for growing numbers of people.

In some East Coast locations, such as Savannah, GA (at Fort Pulaski), and Lewisetta, VA, extensive flooding is expected to occur with tides alone on a regular basis within one or two decades. By 2045, even more places can expect to see extensive flooding, including Ocean City, MD, and Myrtle Beach, SC (at Springmaid Pier). When strong winds or heavy rains do occur on top of elevated seas, the risk of extensive flooding will rise higher still.

#### MORE COMMUNITIES JOIN THE FRONT LINE OF TIDAL FLOODING

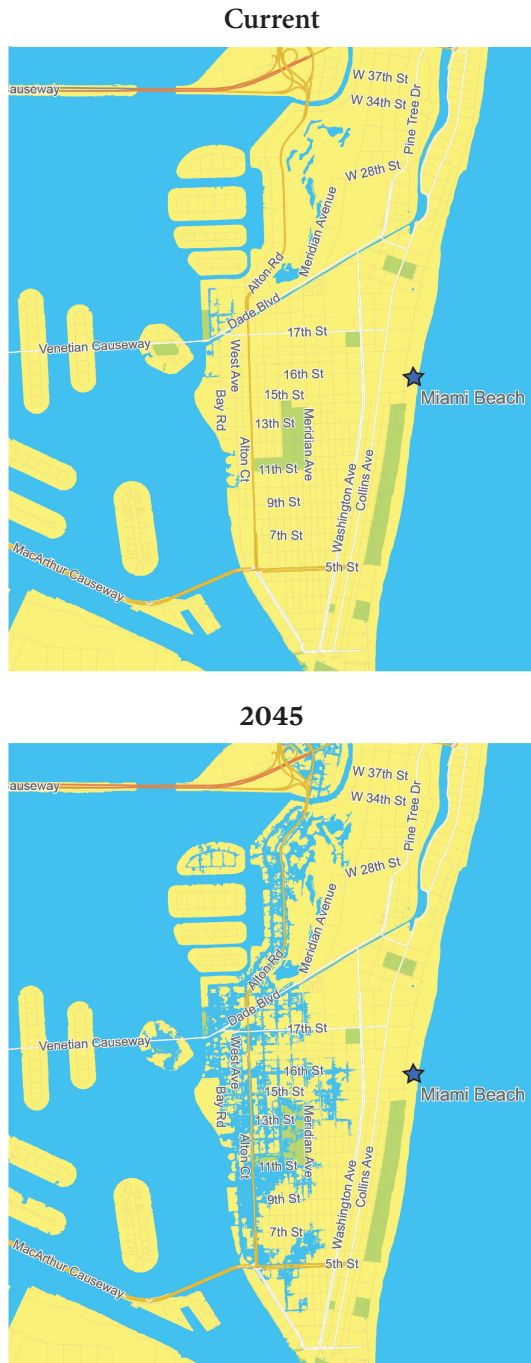
As the reach of the tides expands, communities now unfamiliar with tidal flood conditions will start to see such flooding more regularly—a new normal. In New London, CT, for

example, tidal floods now occur just twice per year, on average, and are limited in extent. By about 2045, however, the city can expect more than 35 tidal floods every year. Other locations with fewer than five tidal floods per year today could see a 10-fold increase in the number of floods annually by 2045.

The Gulf Coast, in particular, can expect to see many new areas exposed to tidal flooding. Several Gulf Coast locations that now see little to no tidal flooding, including Freeport, Rockport, and Sabine Pass, TX, could face 35 to 70 tidal floods per year by 2045.

**By 2045, within the lifetime of a typical home mortgage, one-third of the 52 locations in our analysis would start to face tidal flooding more than 180 times a year.**

FIGURE 7. Expanding Reach of Tidal Flooding: Miami



The top map shows the current extent of “minor” tidal flooding today in Miami Beach. The bottom map shows the extent of flooding that would be possible from that same high tide in 2045 with a higher sea level. By then, Miami can expect to average 230 minor floods per year.

Note: These maps are for discussion and research purposes only. They are not appropriate for detailed analysis.

SOURCES: OUR ANALYSIS; MAP BASED ON DATA FROM NOAA DIGITAL COAST 2014; OPENSTREETMAP 2014; U.S. CENSUS BUREAU 2013.

Given the substantial and nearly ubiquitous rise in the frequency of floods expected in our 52 locations, other communities along the East and Gulf Coasts will need to brace for similar changes. Their susceptibility to flooding will depend on the local topography, their natural and physical defenses, and the measures they take to adapt.

### Sensible Steps for Building Resilient Coastal Communities

Coastal communities and states, and the nation as a whole, need to prepare for near-term changes in tidal flooding, while working hard to minimize longer-term losses through efforts to both adapt to these changes and limit their extent.

#### BUILDING COASTAL RESILIENCE IS A LOCAL IMPERATIVE ...

The lag of several decades between the release of carbon into the atmosphere and the response of the ocean means that more sea level rise and more tidal flooding are virtually guaranteed, and that communities need to act with urgency. Locally, there are many things we can do to help ensure enduring coastal communities, including:

- **Upgrade the built infrastructure in harm’s way.** With help, communities can prioritize and incentivize flood-proofing of homes, neighborhoods, and key infrastructure, such as sewer and stormwater systems.



© Peter Mahony/West 12th Road Block Association

The actual impact on a community facing steep increases in tidal flood events is difficult to predict. Floods will vary in magnitude, and some communities will be better prepared than others. However, the large number of such events and their growing duration and extent has the potential to cause deep disruption, as is already the case here in Broad Channel in Jamaica Bay, NY.

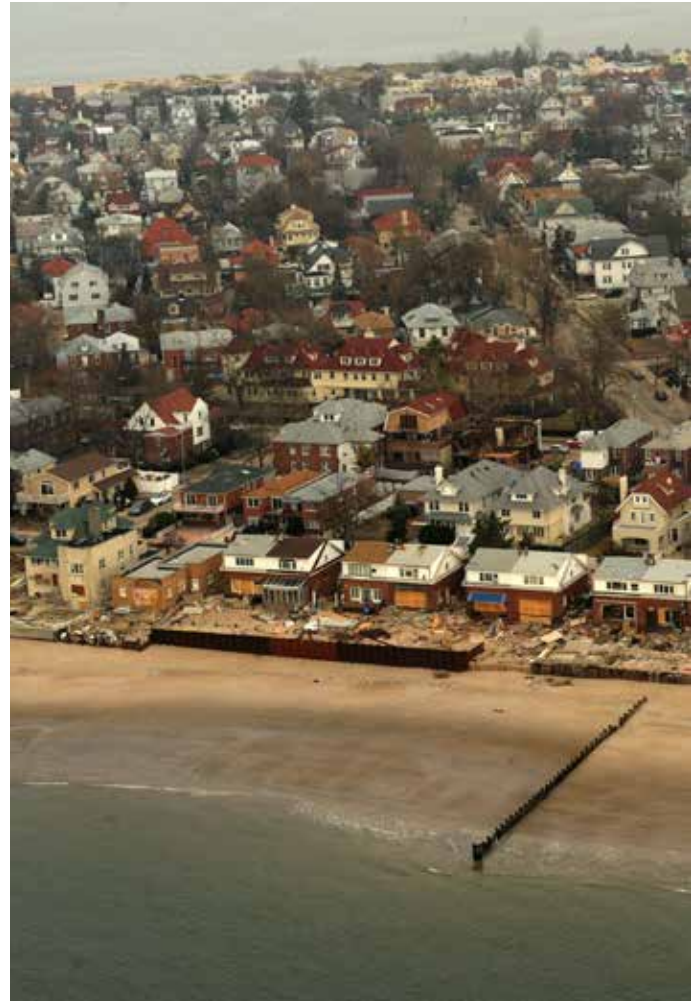
- **Avoid putting anything new in harm's way.** Communities can use a range of regulatory and planning tools to curtail new development in coastal locations subject to tidal flooding now and in the future.
- **Consider the risks and benefits of adaptation measures.** Some measures to limit the impact of coastal flooding can provide multiple benefits, while others can alter shoreline dynamics and damage neighboring areas and ecosystems. Decision makers need to ensure that a rush to protect coastal communities builds broad-based resilience.
- **Develop a long-term vision.** Communities that create a vision for both near-term protection and long-term resilience in the face of sea level rise—and craft plans for building better, safer, and more equitably—will be best positioned to thrive in the years ahead.

#### ...AND A NATIONAL ONE

But local communities can't go it alone—coastal challenges are too great, the costs are too steep, and too many people are at risk. Instead, we need a coordinated, well-funded national response to our country's coastal vulnerability involving federal, state, and local collaboration. Federal and state governments can help build local resilience by supporting, incentivizing, regulating, and even mandating action. They can:

- **Build and maintain a coastal monitoring and data-sharing system equal to the threat.** Key federal agencies can sustain and expand efforts to monitor and project sea level rise and flooding, and ensure that local decision makers have access to the data.
- **Encourage or mandate the use of good scientific information.** Agencies can require that communities and other applicants for state and federal funds use the best available data, and demonstrate that new development and redevelopment projects can withstand projected tidal flooding and storm surges.
- **Support planning.** More federal support for state and local planning and collaboration can accelerate efforts to build coastal resilience.

*A near-term increase in sea level rise and tidal flooding may be locked in, but changes later this century and beyond are not fixed.*



Joseph Augustino/FEMA

*With roughly a third of the U.S. population living in coastal counties, we are in many ways a coastal nation, as this view of the New York coastline illustrates. There is much that localities, states, and the country as a whole can do to ensure enduring coastal communities. One sensible step is to design and build for greater resilience, especially in the wake of disasters, as the state of New York is working to do in the aftermath of Hurricane Sandy.*

- **Mobilize funding.** Adapting to sea level rise will require major, sustained investment. Federal policy makers need to develop new funding sources to support resilience-building efforts at the state and local level.
- **Improve risk management.** The true costs of living on the coast are not reflected in the price of flood insurance and other risk management tools. But big increases in the cost of insurance are hard for many to bear. Federal incentives to reduce some property owners' risks and costs can aid the transition to a more solvent flood insurance system and better risk management.
- **Ensure equitable investments.** Federal investments in coastal resilience can prioritize households and communities with the greatest needs.

- **Reduce heat-trapping emissions.** A near-term increase in sea level rise and tidal flooding may be locked in, but changes later this century and beyond are not fixed. To slow the rate of sea level rise—and enable coastal communities to adapt in affordable and manageable ways—we must reduce our global warming emissions.



© Flickr/Chesapeake Bay Program

*Flooding in Annapolis, MD, driven by rain, wind, and tides suggests the scale of flooding that certain tides alone could bring—absent proactive measures—over the next several decades.*

**THE HARD TRUTH: WE FACE FUNDAMENTAL LIMITS TO COASTAL ADAPTATION**

As sea level rises, even our best protection efforts will not suffice in some areas in the face of rising tides, waves, and storm surges.

In certain locations, shoreline dynamics will make it impossible to build structural defenses. Residents, business owners, communities, and ultimately the nation may reach their capacity to fund costly measures. People may also simply be unwilling to face ever more frequent flood-related disruptions. As we reach these and other de facto limits to coastal adaptation, communities will face the prospect of shifting back from the shore. If we plan well, though, we can sustain our communities by pulling back from the most affected areas before flooding becomes too disruptive.

These limits will arrive sooner in those areas exposed to greater risks, those with more fragile ecosystems and limited natural buffers, and those that are less well-off economically. Our coasts will also face these limits sooner if we allow climate change and sea level rise to grow into an even greater crisis.

***Leaders at all levels of government need to take seriously the risks facing people living along our coasts and the urgent need for action.***

**TO LIMIT FUTURE SEA LEVEL RISE AND SUSTAIN COASTAL COMMUNITIES, WE MUST CURB CARBON EMISSIONS**

Global emissions are rising rapidly, and are on a trajectory to push surface temperatures more than 2°C (3.6°F) above the preindustrial average—the threshold beyond which scientists say “dangerous” climate change becomes unavoidable. To stay below this threshold, and slow the rate of sea level rise later this century and beyond, global carbon emissions need to peak and begin to decline by the end of this decade.

Leaders at all levels of government need to take seriously the risks facing people living along our coasts and the urgent need for action. And communities faced with tidal flooding need to hold their local, state, and national leaders accountable for taking strong action to both adapt to rising seas and mitigate global warming. As a nation, we need to commit to the challenge today, treating the resilience of our coasts as a century-long project—one that requires a concerted early push, one to which we commit for the long haul, and one that enables communities to thrive even in the face of encroaching tides.

FIND THE FULL REPORT AND THE SUPPORTING TECHNICAL DOCUMENT ONLINE:  
[www.ucsusa.org/encroachingtides](http://www.ucsusa.org/encroachingtides)

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