New England's rivers are central to our region's history and to many towns' landscapes. Yet they also periodically flood. River floods in New England have again and again damaged streamside properties that were built on the misguided assumption that rivers always remain in place. Here, the Hoosic River tears down a building in North Adams, Mass., in 1927 (now the site of River Street Package Store).

I. An Introduction to River Floods in New England: Common in History, Commonly Destructive Today

In August 2011, Tropical Storm Irene ripped into western New England. More than the storm itself, it was the high-flowing rivers and streams, normally some of the region's most beloved resources and landscapes, which caused the worst destruction and greatest costs. Why, and how? Four years later, there are still too few people who understand the connection between rivers and flood damage – or realize that there are ways for New England communities to reduce such damage in the future. This report points to practical policy solutions at federal, state and regional levels that can support New England communities to become more resilient to river floods – more river-smart (see box at top).

"River-Smart"

Managing rivers and riverside landscapes, as well as our own actions and expectations, so people and communities are more resilient to river floods. Specifically: reducing flood severity, flood damage, and flood costs by understanding and accommodating the natural dynamics of rivers and river floods.

Crumbling house on Flower Brook, near the confluence of the Mettowee River, in Pawlet, Vermont after Tropical Storm Irene, 2011

In parts of western New England, Irene dumped over seven inches of rain in 12 hours.[1] Water flowed down steep slopes and turned small brooks into raging torrents. Flooded rivers tore at stream banks with enormous force, and undercut road crossings and bridges. Houses and buildings that formerly stood alongside these streams and roads collapsed. In some places, the river torrents carved new channels through roads or property.[2]

Once the raging rivers reached more level terrain in the valleys below, they spread over their floodplains, and slowed down. There, they deposited the rocks, soil, and debris they had carried down from steeper reaches, leaving thick sediment deposits. Much of this sediment will enrich floodplain farms for years to come, but in the short term, the floods and deposits destroyed many crops.

Also, because the floods during Irene were so large and powerful, the sediments were not always what a farmer wants–in many places they were mostly gravel, rocks, boulders, and debris, and sometimes they carried contaminants. Many houses were left with thick layers of silt.[3] Some riverside houses were left with huge piles of debris.

Some of the most costly damage was inflicted on roads, bridges, and buildings. In Vermont alone, over 500 miles of road were damaged, and thirteen communities were rendered inaccessible when all routes in and out of town were washed away. These towns were cut off from stores, hospitals, and other necessary services. Additionally, there were over 70,000 power outages across the state. It is estimated

Farmland in Granville, Vermont covered in sediment after Tropical Storm Irene.

that towns and cities needed $140 million to recover just from the damage to municipal infrastructure.[4]

By now it is old news that Tropical Storm Irene caused tremendous damage in New England. Too few understand, however, what caused most of the damage, why, and how – and what they might be able to do about it.

This report is founded on scientific understandings of river floods, informed especially by the science of fluvial geomorphology. Fluvial geomorphology is the study of the ways that rivers move and change over time, focusing especially on how the flow of water interacts with the movement of sediment – dirt, sand, gravel, boulders – and debris such as downed trees and branches. It also considers how the movement of water, sediment and debris interacts with the immobile features of the landscape, from bedrock canyons to human-built infrastructure like dams, bridges, and reinforced stream banks. Understanding these dynamics explains the shapes of rivers and their landscapes, and how these change, sometimes slowly and sometimes suddenly – including the ways rivers may carve into, or add material to, their banks, beds, and floodplains.[5]

River flood deposits can be serious hazards to lands and livelihoods.

Understanding rivers in this way helps to show why river floods are sometimes so damaging in New England. River floods in New England can be sudden, unexpected, and damaging, but they have long been part of the region's landscape. It is no coincidence that centuries ago many of the region's rivers earned names like "Mad River" and "Roaring Brook." Sometimes, a storm is so big – like Irene in 2011, or Vermont's Flood of 1927 (see Example 1: River Floods in New England, Past and Present, p. 11) – that the damage is devastating across a large part of the region. However, every year, some parts of New England face more commonplace and local river floods.

In the past, the destructiveness of floods was reduced by interaction with the landscape, and by human adaptation. Flooded rivers spread out over floodplains, created and moved meanders, picked up and dropped sediments and debris as they gathered and then dissipated energy. People adjusted when rivers moved, and harvested from the bounty of newly enriched floodplain soils and rejuvenated fisheries habitat.

By the industrial era of the 19th century, New Englanders were building towns and cities with fixed structures and concrete river channels and canals along many rivers.[6] In the countryside, people straightened rivers, drained wetlands, and filled braided river sections to consolidate farmland. They built berms along railroad tracks, and later, along roads, to stop water flow. When major floods damaged a large number of towns and cities, we responded by building large dams on many of the region's rivers, to retain some flood waters behind the dams, and by building levees. We did this especially after the major floods of 1936, 1938, 1948-9, and 1955 (see Example 1, p. 11).[7]

Thanks to the success of flood control measures, and because we were spared a regional flood on the scale of Irene for about forty years, we increasingly perceived the region's rivers to be static in the landscape. We built more houses, buildings, roads, and other structures close to rivers and streams. We armored even small tributaries, believing that our hard structural approaches to flood control – dams, levees, revetments, deepened channels – made us safe.[8] We increasingly tried to treat all river channels as fixed in space and time.

Example 1. River Floods in New England, Past and Present

Major New England floods of the 20th century: 1927, 1936, 1938, 1949-50, 1955

Because of New England's ample rainfall and steep terrain, it has a long history of large, destructive river floods. Tropical Storm Irene in 2011 brought the worst floods many Vermonters had ever seen; but a few Vermonters, now in their 90s, remembered one that was worse. In 1927, after a particularly wet October, in early November a hurricane came up the Atlantic coast, stalled in Vermont's mountains, and dropped six or more inches of rain over three days. As with Irene, rain that fell in steep river valleys accumulated quickly into raging torrential streams and rivers. Some 84 Vermonters died in the resulting floods across the state. A decade later, southern and coastal New England experienced similar scales of river floods and devastation. The flood of 1936 remains the flood of record for much of the southern Connecticut River Valley, as well as other river valleys in western Massachusetts and Connecticut, while the flood of 1938 battered coastal communities in Connecticut,

Springfield, Vermont looking toward Falls Bridge, 11/4/27

Massachusetts and Rhode Island. There were also major regional-scale river floods in New England in 1949-50, and 1955.

A recent, more localized disaster: Suncook River, New Hampshire, 2006

Regional-scale floods bring much-needed attention to the problems that can be caused by river floods. However, the media attention on large-scale extreme floods can obscure the fact that there are more localized floods in parts of New England every year, some that do considerable damage. One of the most damaging local events in recent years occurred along the Suncook River in New Hampshire, a tributary of the Merrimack. Following extreme rain in the state on May 15 and 16, 2006, the Suncook overflowed its banks and carved a new path, while nearly two miles of the old river channel was left dry. The river's new route was shorter and steeper, so the water sped up, and carried and eroded more sand. In the weeks and months that followed, the channel cut down more than 10 feet, and stream bank after stream bank slid into the river. Three dozen homes have had to be purchased so home owners could move to safer locations, and the river is now down-cutting into its bed upstream in what is known as a migrating headcut; this has the potential to undermine the Route 4 highway bridge in the future.

Learning from our rivers' past and present

River floods are natural products of New England's variability in weather and terrain, and they have made and remade our landscapes for millennia. Our fascination with extreme floods and extreme flood damage has too often led us to dam and armor rivers, resulting in growing complacency that we can count on their new stability. The damage caused by Irene in Vermont and western Massachusetts, and the problems caused by the Suncook's sudden channel shift in New Hampshire, show that we have not – and cannot – build our way to total river stability. It is time to accept and understand river floods better, so we can live with rivers rather than pit ourselves against them.

Suncook River, 2003

Suncook River, 2014

New England rivers now have much less room to spread out, meander, move, lose volume, and dissipate energy than they used to, and there are more built structures in their way. When they flood, they swell even more than before, exert more force, and often carry more sediment and debris. These more powerful flooded rivers have the ability to blow out even our new modern infrastructure – often with catastrophic results for roads, bridges, buildings and people. Replacement costs are enormous, and often repeated. In the 1990s, for example, a series of floods in parts of the state of Vermont wreaked havoc in numerous communities, and recovery cost nearly $60 million dollars. About 50 percent of this cost was avoidable, had structures been built better able to accommodate flood waters, sediment and debris.[9]

In one place or another, rivers regularly break through our barriers and move parts of the landscape that we have treated as fixed – finding ways to dissipate their energy despite our attempted restraints. It is then that we face the worst damage, and experience the most intense and unwanted surprise (see Example 1: River Floods in New England, Past and Present, p. 11).[10]

Floods are often talked about as 100-year floods, 50-year floods, 10-year floods, etc. These terms have taught people to think that major floods are rare events, and that if they experienced one recently, they are safe for decades to come. Unfortunately, this is poor terminology; a 100-year flood means a flood that has a one-in-one-hundred chance of happening this year.[11] Given the randomness of probability, it is quite possible to get two large, region-wide one-hundred-year floods in less than three years, as New England did in March 1936 and September 1938. Even the more accurate one-percent-annual-chance phrase now in use[12] can be misleading. There is enough weather and terrain variability across New England, across its many hundreds of rivers, that every year, there is some place in the region that gets a one-percent-annual-chance flood.[13] To avoid these misunderstandings, in this report we use even this terminology with considerable caution. Instead, we emphasize that significant river floods are common events in this region, not rare or unlikely, and we all need to learn to live with them.

In the future, the problem is likely only to worsen. Climate change will have different effects in different parts of the world, but in New England, one of the chief predictions is that extreme storms will become more extreme and more frequent.[14] New England has been warming since the industrial revolution, and is now warming about 0.75 degrees Fahrenheit every ten years.[15] As the temperature warms, the air holds more water. By 2100, New England's precipitation is predicted to increase 10% to 30% depending on the season.[16] Additionally, storms will likely become more extreme. Summers will have more intense hurricanes and tropical storms. Winters will have more rain and earlier spring snowmelts. Together, these trends means more water moving more quickly into the region's rivers, and an increased frequency of damaging river floods. There is a clear need to think ahead, improve flood and river management, and prepare for the storms to come.

A meander cut through a road (Route 100).

From Science to Management to Governance to Policy

Studying river systems as a whole, and considering all the factors that change their behavior, helps us predict what they are likely to do. This benefits flood mitigation and preparedness. If we can anticipate the movements of a river, and assess what infrastructure is ill equipped or at risk of failure, we may be able to move people out of harm's way, and improve or move buildings and structures. This points to a different approach to managing rivers and streamside lands and landscapes, in which we adjust to and accommodate river dynamics as much as possible to allow river floods to dissipate force and volume.

However, management prescriptions are often difficult to apply in practice, and even more difficult to turn into workable government policy. This is especially so in a region like New England, with six very independent states and about fifteen hundred individual municipalities, where most land is privately owned, and people long ago built next to rivers.

This speaks to the issue of governance. Governance includes but goes beyond governments; it is all the ways we organize shared decision-making. In New England, the municipalities (towns and cities) often bear the primary responsibility for land use decisions, emergency preparedness and response, and infrastructure construction and repair. Yet in the areas of the region where damage from river floods is often worst – in the mountainous and hilly regions, and the valleys just below – towns tend to be small, with a few dozen to a few thousand people. With limited staff, budgets, and expertise, it is difficult for them to manage all the responsibilities that are needed in order to understand, prepare for, and respond to river floods.

Numerous state and federal government programs work to help New Englanders prepare for and respond to floods. Many are informed by excellent technical information, offer valuable resources, and are staffed by skilled and dedicated employees. Nonetheless, they can feel distant, bureaucratic, and complicated for many people living and working in New England's small towns. It can be challenging for communities to navigate political and administrative processes. Some residents have even expressed the opinion that sometimes federal and state government policy seems to be more about making rules about what townspeople and landowners cannot do, and less about helping them.

At the same time, it is a challenging time to try to build effective government programs that can make a difference across New England's hundreds of municipalities. For the dedicated government employees doing their best to administer quality programs with shrinking budgets, it can feel like an unmanageable task to address the needs of the hundreds of municipalities in each of the states, and to provide the kind of close technical guidance to every municipal official and landowner who could use it – especially when those same officials and landowners may be simultaneously complaining about government's ineffectiveness.

The good news is this: our research has taught us that creative people across the region have figured out ways to make positive change happen. We have found that there are ways that state and federal governments can continue to do their important work, from regulation to grant programs to technical assistance, and be more helpful to New England's towns and cities and their residents – while still working within their budgets and authorities. Often in collaboration with communities and nonprofit agencies, innovative policy and agency leaders are finding creative solutions to problems and limitations, and are helping New England municipalities to become more river-smart.

Chapter II describes in more detail the science of river movement and change, and the lessons for management. The issue of governance, policy, and the lessons from our research are explored in Chapter III. Chapter IV provides our five targeted recommendations for policy change.