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Supporting New England Communities to Become River-Smart: Policies and Programs that can Help New England Towns Thrive Despite River Floods

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Cover Photo: Confluence of Chickley and Deerfield Rivers, Charlemont, Massachusetts, September 18, 2011.

This photo illustrates some common river flood processes and dynamics, and illuminates factors that influence the extent of damage during river floods.

During Tropical Storm Irene in late August, 2011, the number of new landslides was unprecedented. These landslides contributed a large amount of sediment to the rivers of Vermont and western Massachusetts. Within Massachusetts, damage from Tropical Storm Irene was most severe in the Deerfield River watershed. Yet, damage was not consistently severe throughout the region.

Here, in this photo, the Chickley River enters the Deerfield on the left. The Chickley had swollen enormously, causing tremendous damage in the town of Hawley. It brought high volumes of water and sediment into the Deerfield. The Deerfield River also flowed far out of its channel, as seen in the light-colored over-wash on the right bank, opposite the Chickley River. Yet structural damage at the confluence of the Chickley and the Deerfield River was limited. Why? For one thing, the river could access its floodplain. The overwash represents an overflow channel through the floodplain, where the river dissipated energy and volume. Structures were built back from the channel. Bridge spans on state Route 2, which was heavily damaged elsewhere, were also large enough here to accommodate flows of water, sediment and debris. The river's access to its floodplain here may have reduced downstream damage, by reducing the power of the river's flow.

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riversmart communities

Supporting resilience to river floods through science, policy, and community outreach

http://extension.umass.edu/riversmart/

The RiverSmart Communities program combines social and river science, institutional and policy research, and community outreach at the University of Massachusetts Amherst to research and address river floods in New England. It is our vision that river management can restore the environmental integrity of rivers while ensuring that New England communities thrive in a world where floods naturally occur. To make this vision possible, our work aims to help New England's communities become ***river-smart.***

A key goal is to offer ideas and tools that can be used by people and groups across New England – land and river managers, riverside property owners, policy makers, government agency staff, community leaders, grass-roots activists, and others – so they can creatively build and advocate for systems that work for their own states and communities.

We encourage your use of our educational and outreach materials to promote sustainable river management in your community, though ask that you credit our work. In this spirit this report is licensed with a Creative Commons license that allows free use of any information or graphics as long as the source is credited.

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.

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Preface

This report aims to help New England's communities and their residents, as well as the governments that serve them, to better deal with and adjust to river floods. It points to practical policy solutions at federal, state and regional levels that can support New England communities to become what we call river-smart.

In considering New England's communities, we focus on the small towns in the region's mountainous areas that are most at risk for damage from river floods. These often have scarce resources and limited ability to access help from the state and federal governments. We also recognize the constraints of government agencies that serve New England communities. Budgets are tight, personnel have been cut, and efforts to make new policy through legislation or rulemaking can face gridlock, opposition, or long, complex administrative processes.

Yet our research has given us hope. We have learned that creative people across the region have figured out ways to make positive change happen. We investigated seven case studies in which people, organizations and governments have, despite challenges, figured out ways to help New England communities become more river-smart.

The first three chapters of the report provide background for policymakers, agency staff, community leaders, and members of the public. Chapter I emphasizes that river floods have been common throughout New England's history, and remain destructive today. Chapter II provides a primer on the science of dynamic rivers, illuminating how and why river floods can be so unexpectedly destructive. It ends with three lessons on how rivers and lands can be managed to minimize and mitigate river flood damage. Chapter III outlines the assistance that New England municipalities need in order to undertake this river-smart management, and summarizes key federal programs that provide some of this assistance. An overview of our case studies shows ways that creative organizations are adding support beyond existing policy.

Building from this background, Chapter IV identifies five policy changes that, with modest fiscal resources and limited regulatory change, can make the most immediate and long-term difference for the future safety and wellbeing of New England communities. Our policy recommendations are:

1: Develop Fluvial Hazard Assessments

2: Upgrade Vulnerable Stream Crossing Infrastructure

3: Support River-Smart Planning and Mitigation

4: Provide Outreach and Training on River Dynamics and River-Smart Practice

5: Designate, Recognize and Support River-Smart Regional Intermediaries

Our report does not spell out exactly who should take on all these tasks; New England is too diverse in the ways it structures its river and flood management, and in the ways federal, state, regional and local governments share their authorities, to offer such prescriptions. Instead, we offer clear ideas and tools that policy makers, government agency staff, community leaders, and grass-roots activists can use to creatively build and advocate for systems that work for their states and communities. For each recommendation, we provide tangible examples of people, places, and institutions in New England that are already making these things happen – examples that show some of the ways these recommendations can be put into practice.

We intend this summary report to be widely comprehensible and useful to people who care about New England's communities and their abilities to withstand and manage river floods. To make this report more readable, we have included citations only in Chapters I-III. More detailed background, examples, and references for the recommendations and featured case studies of Chapter IV will be provided on the RiverSmart website, https://extension.umass.edu/riversmart.

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.

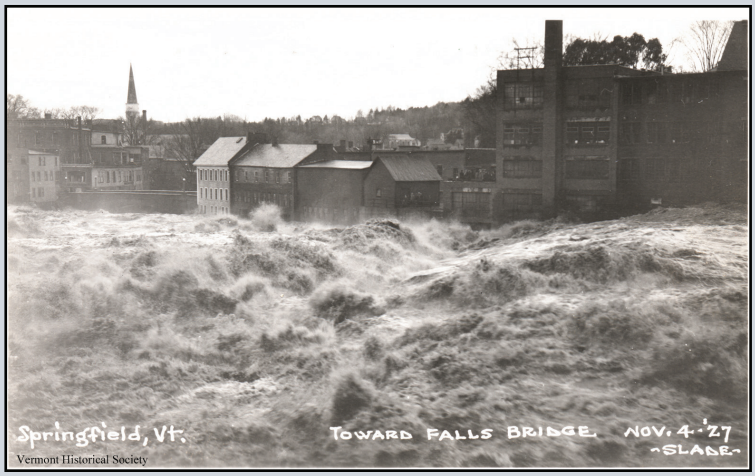
By the industrial era of the 19th century, New Englanders were building towns and cities with fixed structures and concrete river channels and canals along many rivers.[6] In the countryside, people straightened rivers, drained wetlands, and filled braided river sections to consolidate farmland. They 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

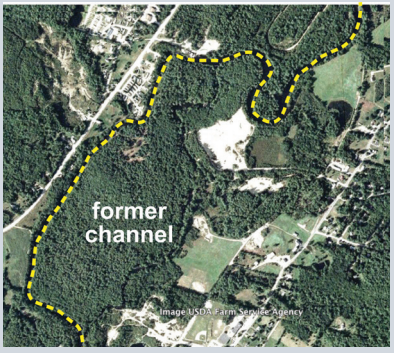
Massachusetts and Rhode Island. There were also major regional-scale river floods in New England in 1949-50, and 1955.

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

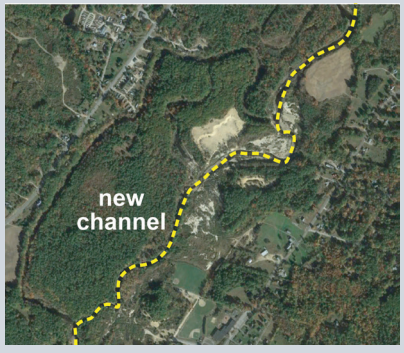
Regional-scale floods bring much-needed attention to the problems that can be caused by river floods. However, the media attention on large-scale extreme floods can obscure the fact that there are more localized floods in parts of New England every year, some that do considerable damage. One of the most 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.

US Route 4 in Vermont was no match for the force of water, sediment and debris raging down into and along the Ottaquechee River during Tropical Storm Irene.

II. River Science, River Floods, and River-Smart Management

Why Should We Care About Rivers and River Management?

Rivers are vitally important resources in New England. Many of our towns and cities get their drinking water from the region's clean, bountiful rivers. Rivers sustain fish and other animals, myriad plants, and a range of ecosystems. New England's rivers powered our nation's earliest factories, and still produce electricity. Rivers connect us – from mountain to sea, from rural countryside to urban metropolis. Rivers are also places – they provide some of the most iconic landscapes in New England, many of our most beloved destinations, for locals and tourists alike.

Rivers are also active participants in making our landscapes richer and more productive. Rivers transport sediment and nutrients from hill slopes to valleys, down to floodplains, broad lakes and larger rivers, and finally out to the sea. These processes nourish floodplains, farms, and riparian areas, and provide benefits all the way to the coast, helping to maintain sandy beaches and barrier islands (thus reducing the negative effects of sea level rise). Rivers move gravel into stream reaches to form spawning habitat for fish, and dig pools where aquatic creatures can hide, find cool water, and grow. They carve meanders, pools, rapids and embankments where people love to recreate. Rivers even allow species to go up hill – creatures as diverse as insects, salamanders, raccoons, and people follow river meander corridors upward as well as downward to find new habitats, homes, mates, and communities.

However, rivers are powerful natural entities. They can cause damage to life, property, and habitat when they flood. This is especially so if we do not understand or appreciate, and are unprepared for, the ways rivers move and change over time and space. It is vital to interact with rivers mindfully when building and living near them.

The Science of Fluvial Geomorphology: Understanding Why and How Rivers Move and Interact With Their Landscapes

Rivers and landscapes shape one another. The study of how a river moves and interacts with its landscapes is called fluvial geomorphology. "Fluvial" means "relating to rivers and streams." "Geomorphology" is the study of the shape of the landscape, and the dynamic physical and chemical processes that form and change it.

This section outlines some general dynamics and processes of fluvial geomorphology, and lists several key insights about river floods.[17]

Dynamics and Processes: How Rivers Move and Shape the Landscape

The two starting points for understanding how rivers move and interact with their landscapes are first, that streams and rivers include sediment and debris as well as water; and second, that as they flow, they apply force on, and release material to, the landscapes around them (see Example 2: Inundation Hazards Versus Fluvial Hazards, p. 16).

As the water in a stream or river travels, it pushes on the rocks, sands and silts in its bed and bank. Often it dislodges some of these sediments, and carries them into the channel and downstream. The faster the water in the river moves, the bigger pieces of rock and sediment it can carry. Most rivers can move sand and silt under normal flows, and when moving very fast during high flows, they can carry bigger rocks and boulders. When the river carries a lot of water, it can also carry more sediment.

Key Insight #1:
Rivers carry more than water. Rivers in flood carry and move large volumes of sediment and debris, and travel with tremendous velocity and force.

Example 2. Inundation Versus Fluvial Hazards: Different Kinds of Flood Hazards

Downtown Wilmington, Vermont at the height of Tropical Storm Irene

A house destroyed by Tropical Storm Irene hangs over Marshs Brook, a tributary of the White River in Rochester, Vermont

The most common notion and image of floods is of rising water. Rising water causes inundation, or immersion in water. Many times, though, the most damaging aspect of river floods, and the one that takes people by the greatest surprise, is fluvial damage – either **fluvial erosion** or **fluvial deposition**. This is not caused by rising water, but by the power and force of moving water, sediment, and debris.

If the main threat of a flood is inundation, or rising water, the key variable that affects flood risk and damage is the elevation of lands, homes, and structures. Lower elevation areas are more likely to be inundated, like a bathtub might fill with rising water. The solution is to move structures to higher ground, to elevate homes and structures, and, where needed, build protective structures to keep out water.

However, there are many areas of higher elevation that may be safe from inundation, but are at great risk of fluvial erosion. This is because flood waters can undercut banks and hill slopes, causing small and large landslides. For example, this home along Vermont's White River near Rochester was likely at high enough elevation that rising water never touched it, but the damage it suffered from the bank eroding beneath it is clear. Some areas that are at risk of inundation may also be at great risk of fluvial deposition (see photos pp. 9 and 10).

New England communities remain ill prepared for the **fluvial hazards** that come with river floods. It is time we stop seeing floods only as inundation. Predictions of inundation risk, and mitigating for inundation, cannot prepare towns or property owners sufficiently for problems like catastrophic streambank collapse, or inches to feet of deposited sediment. Some measures used to protect against inundation – like building berms and levees – can make fluvial hazards worse.

The long-term, cost-effective solution to reduce fluvial hazards and damage is to allow rivers room to move as much as possible – to flood their floodplains, and to meander and braid. Where this is not possible, it is important to mitigate, by allowing rivers to move in other locations.

When a river slows, sediments settle out. The smaller the particles are, the farther the river can carry them downstream. The settling out of sediment, called deposition, can occur on the stream bed, on the inside of river bends, and on flatter areas next to rivers and streams.

Watershed patterns: The power of gravity and slope

In a watershed – that is, in an area of land which drains into a particular river – these dynamics play out in reasonably predictable patterns. In the steep hill slopes, more sediment is eroded than deposited. In flat valleys, more sediment is deposited than eroded. Over long time periods, material from hill slopes travels down slope to become stream bed gravel and floodplain soils. Eventually – over decades, centuries, millennia, or sometimes just days or hours – it is carried out to the sea.

The downstream movement of sediment is a long-term pattern, and is accelerated during river floods. When it rains in mountainous areas, water runs down the hill slopes. When rain water first enters a stream channel, the streams are often steep, small, and fast-running. Several of these soon join to form slightly larger streams. When there is a lot of rain in a

In this watershed, all land in the dark green area drains into the same river.

short amount of time, these small streams can swell enormously, quickly reaching the volume normally found in the mainstem river in the valley far below.

Key Insight #2:
Small streams can swell enormously during floods, rising much higher than their banks.

As these swollen mountain streams run downhill, they exert tremendous force on their stream banks and beds, and on any trees, structures, or other normally fixed-in-place parts of the landscape. Stream banks slump into the river. Bridge abutments crumble. Trees topple over entirely. Now, rocks, soils, bridge abutments and trees all become part of the raging torrent, and they also exert force, smashing into further roads, stream banks, and trees.

Key Insight #3:
High, fast, powerful flood flows can rapidly erode, undercut, and carry away parts of their landscapes.

Only when the river finally reaches an area where it can spread out, or the slope decreases, does the water slow down and lose energy. The immense quantities of sediment and debris carried downslope can no longer be carried by the slower, less powerful water, and the river drops its load. Several hours or days later, as the flood recedes, it leaves behind much of what it took from the upstream hill slopes and stream banks (see photos pp. 9 and 10).

Key Insight #4:
The material eroded by fast-moving floodwaters is deposited somewhere else, wherever the river slows down and spreads out – in floodplains, in the inside of river bends, in flatter more open valleys far below, or even in people's homes.

Human activity influences how much sediment and debris a stream erodes, carries, and deposits as it travels downhill. Urban areas and other areas with impervious surfaces accelerate run-off into streams and rivers, increasing a river's volume and its erosive power. Dams can trap sediment, but downstream of a dam, a sediment-starved river may also become more erosive.

When people log forests on steep slopes, or excavate ground to build large housing complexes, or leave steep farmland exposed without a cover crop, rain more easily erodes away the exposed soils. When people build roads and add fill, they provide relatively easy-to-mobilize gravels and rocks that a flooded stream can carry away. In New England, where the last great logging era was around the turn of the 20th century, sediments eroded from hillsides during that logging period are still moving through many of the region's river valleys. These are still being mobilized in today's river floods.[18]

Key Insight #5:
Human land-based activities often accelerate the movement of sediments, soils, debris, and even parts of the landscape from hill slope to valley. This effect can last decades or centuries.

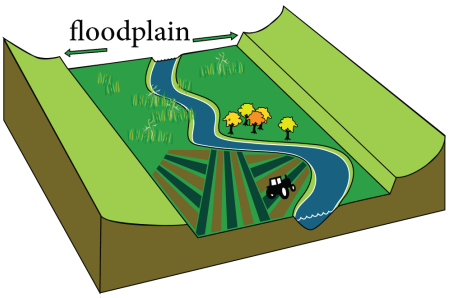
All rivers have variable flows across the days, seasons and years. Because of this, erosion and deposition also vary over time. Rivers and their landscapes can be shaped gradually, eroding their banks during normal high flows, incorporating sediment from small slumps, then dropping it elsewhere in slight rearrangements of the river channel and flow. However, during large river floods rivers can change their landscapes suddenly and on a much larger scale.

Over time, this persistent movement of water, sediment, and debris continually makes and remakes river channels, floodplains, and the riffles, pools and other features of aquatic habitat. The destructive force of river movement and floods is also a creative one on which people and other species depend.

Rivers and Floodplains

A river constantly moves and changes in response to the terrain it crosses, the amount of sediment it carries, and the water flowing through it. If something happens to change these – more water or sediment enters the river, sediment is taken out of the river bed, a dam is built, etc. – the river will shift, flow faster or slower, erode more or deposit more, or even completely leave its channel to form a new one.

A river does this mainly in its floodplain and adjacent lands. A floodplain is the low-lying, flat area where rivers flood and deposit sediment. When rivers flood their floodplains, they renew the soils, providing fertile soil for agriculture as well as for wild plants and animals. They help dissipate volume and energy, reducing the destructiveness of the flood for communities downstream. Even when a river is not in flood, it is often connected through groundwater flow to its floodplain's soils. This helps provide a richly watered environment essential to many important species. Many animal and plant species take advantage of river-floodplain connections to move to new habitats, feeding areas, and communities.



Key Insight #6:
If rivers are allowed to flood, and to spread out to their floodplains when they flood, they contribute important nutrients and ecological benefits. When waters spread out to the floodplain it also lessens the force and damage of the river flood for those downstream.

The interaction between river and floodplain can lead naturally to changes in a river itself. Floodplain sediments, deposited by the river over centuries and millennia, are relatively soft, and made up of small individual particles that are easy for a river to move. Rivers regularly carve meanders through their floodplains (more on meanders below).

Key Insight #7:
It is in the nature of rivers to move their channels and change their landscapes. This is a constant but highly variable process with some predictable patterns.

Also, sometimes a river flood will bring so much sediment from upslope, or move so much floodplain sediment, that it can create a small obstruction for itself. Then, it often breaks through another part of the floodplain soils, carving a new channel, setting off a new process of erosion and deposition.

People impact rivers' processes. When a floodplain is covered with buildings, roads, and railroads, and is separated from its river by flood barriers built to protect these, it loses much of its ability to diffuse the damage from floods. Instead of being reduced in power and force as it spreads out, a river flood continues to be just as destructive as it travels downstream. Flood control dams can greatly reduce floods, and the watering of floodplains. This may help protect human structures and investments built in floodplains, but it comes with significant costs. Dams require the permanent dedication of valley lands to a reservoir – one reason New England chose in the mid-twentieth century not to build as many large flood control dams as other regions.[19] Flood control by large dams also interferes tremendously with the beneficial functions of floodplains, with the rejuvenation of stream gravels, and with the seasonal river flows needed by many important species.

Key Insight #8:
Floodplains are formed by rivers. If a road or structure is on a floodplain then it resides in a place where the river has run or flooded in the past, and is likely to do so again.

Alternatively, sometimes rivers reclaim their floodplains. This may sound romantic (and it can bring long-term benefit) but it can be a destructive process if there are buildings or other investments in the way. When a particularly powerful river flood breaks through one or more of the obstacles block-

ing its force from spreading out onto the landscape, it often carves easily into the old floodplain soils underneath. Then, it can quickly erode away foundations under walls, roads and bridges.

Key Insight #9:
When people put obstacles in the way of rivers so the rivers cannot access their floodplains, the force of a river flood may break through the obstacles. Alternatively, if the raging river cannot break through, its full force will be retained as it rushes downstream. Either way, the result is often disastrous to human-built structures.

Predictable Patterns of Channel Change

Within a river channel, moving water and sediment interact with curves and features in the stream bank, and with rocks, boulders and vegetation in the stream. These interactions create complex flows – strong currents, for example, or rapids, or circular eddies. These flows in turn influence the shape of the stream bed or channel or bank – particular portions of the river's flow dig channels downward, extend or move meanders, scour holes or pools, or deposit layers of gravel. These dynamics are too complex to predict precisely in any one location, and indeed, the flow and shape of one point in the channel can change significantly from day to day, season to season, year to year.[20]

Key Insight #10:
We cannot know exactly where rivers will move, erode, or deposit sediment or debris, but with an understanding and assessment of specific river processes, patterns and features, we can identify places of high risk.

There are, however, flow dynamics within rivers that are predictable as general patterns. Assessments of these and other patterns and features can help people evaluate likely risks in specific places (see Recommendation 1). The three general processes discussed below reveal locations where structures, stream beds and stream banks are most at risk in a river flood, and some ways our own land use practices may impact these.

Down-cutting With Ensuing Widening

One of the most common processes of river change in much of New England today, and one of the most destructive, is down-cutting (or incision). Down-cutting is a process in which a river deepens itself dramatically, often with significant consequential stream bank erosion. Down-cutting is often unnoticed in its initial stages, because the changes occur below the surface of the stream.

Down-cutting happens most when rivers are confined in straight channels. When a river is confined – that is, when it has strong rock or cement walls or banks on its two sides – it cannot spread out to dissipate volume and force. When a river is straight, it is steeper than if it is meandering, so it increases its velocity and force.

Some parts of rivers and streams are naturally confined and straight – such as steep mountain streams that run through bedrock and boulders. But frequently rivers are confined and straightened because people have built walls, levees, dikes, berms, or revetments in order to pass water quickly through an area where they have investments–houses, buildings, roads, railroads, infrastructure, or farmland. Unfortunately, the consequence is an even faster, more powerful stream.

Streams are also made more powerful when we cover the landscape with impervious surfaces – things like buildings, asphalt, and cement. These prevent storm water from infiltrating into the ground and instead send it directly as surface runoff into the stream, increasing high flows.

A powerful stream applies enormous force on the stream bed. The erosive capacity of the stream is even greater when we excavate the stream bed to make it deeper, or when we dig out the larger rocks, boulders and gravels, leaving the stream bed with exposed finer-grained sediments and soils. A strong, fast, high-flowing stream erodes easily through finer-grained sediments and soils, causing down-cutting or incision.

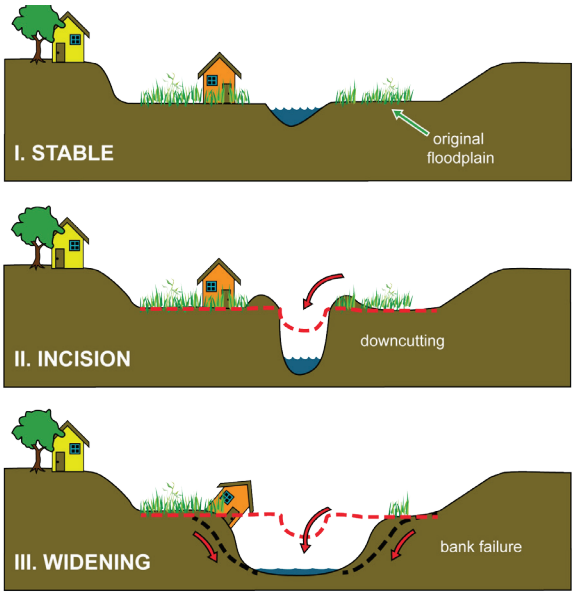
Down-cutting may not initially appear to be a problem for peoples' stream-side investments, which seem protected by bank armor. However, a stream that has down-cut deeply is no longer able to access its floodplain on a regular basis. As a result, high flows that would typically have slowed down and spread out onto the floodplain will now be confined to the small, narrow channel and remain powerful.

Key Insight #11:
Straightened, confined rivers are faster and more powerful.

The stream will eventually dig below the level of the armored channel walls, and erode away the finer sediments until the remaining top layer of the bed has only coarser gravel, rocks and boulders.

This process continues until the bed becomes so resistant to erosion that scientists call it a "pavement" layer. The resistance in the bed becomes greater than the resistance in the bank. Then, the rate of horizontal, outward erosion accelerates, and the river undercuts the armor, levees, or berms, which can collapse catastrophically. Suddenly, the investments that depended on protection from the river are vulnerable. From a stream's point of view, it is re-establishing a floodplain, reclaiming a place to flood and meander. From the point of view of someone who worked hard to protect the human-built stream-side investments, a controlled stream has suddenly become very destructive.

Key Insight #12:
Straightened, confined rivers, especially when they have been excavated, tend to down-cut their beds. A river that has down-cut often then re-widens at a lower elevation. This is likely to be destructive of levees, dikes, berms and other protective structures, as well as the investments they were built to protect.



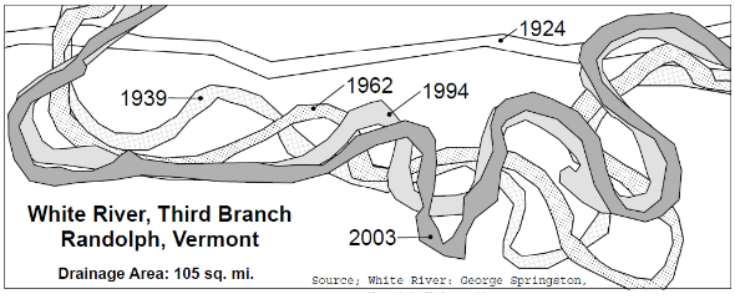
Natural rivers have floodplains where they spread out during high flows (stage I). When we straighten and armor river channels, rivers often undergo down-cutting or incision (stage II). They may widen again at a lower level, as they re-create a new floodplain. This can cause severe damage to streamside built structures (stage III).

Movement of Meanders

A second general pattern is that meanders tend to grow or move over time, causing problems for lands and structures in their way.

Consider why this occurs. For a short stretch, between two meanders, the main flow of the water goes straight. Then, the channel bends. However, the river is not a conscious being; it does not anticipate the bend. The main flow of the water continues straight. It flows into the outside edge of the bend. Only then, when there is no longer anywhere to go forward, will the flow be forced back out and around the bend. But in the meantime, that flow has exerted force on the stream bank. Here, on the

Key Insight #13:
River meanders and braids naturally move over time and space.



Natural rivers move around over time, like this meandering river.

Rivers may also form complex channels like this braided Central American river.

outside edge of the meander bend, if there is erodible sediment, a stream is likely to erode it away, and the meander bend is likely to expand outward.

As the force of the water hits the outer edge of the meander bend, much of it also is pushed down, and so the river will also erode downwards, digging pools at the outer edge of the meander bend and undercutting the riverbank.

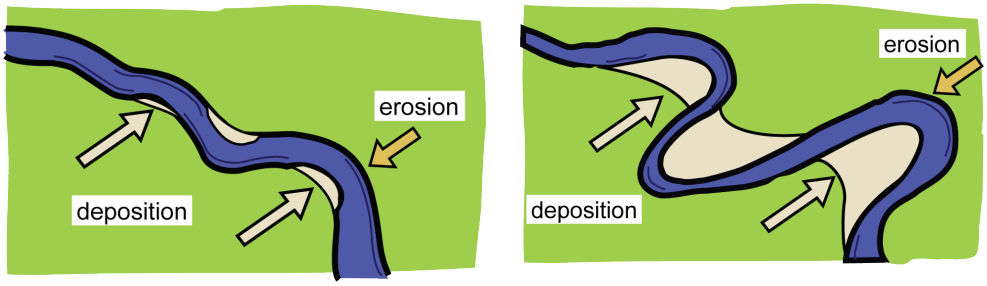
The stream bank above the outer side of the meander bend can become a vertical, backward- moving embankment. Buildings on the vertical sandy embankments above river meander bends may be at particular risk of collapse during river floods.

In steeper, more confined valleys, erosion may be slower, and meanders may not be able to move outward. Instead, erosion is likely to be displaced to the opposite bank, just downstream. In this case, the process of continual erosion and sedimentation may move meanders in a down-valley direction over time. The result of these processes is that over time, meanders tend to get pushed farther and farther outward (in sandy valley bottom settings), and/or down valley (in more mountainous rivers).

Key Insight #14:
Erosion of stream banks is often enhanced at the outside of the meander bend – both outward and downward. Vertical, sandy embankments at meander bends are often evidence of continual undercutting.

In a natural river, these processes may be slow and reduced because meanders decrease a stream's slope and therefore its power. Some erosion and deposition will continue, and over a long or even medium time period, river meanders

Houses at high risk of fluvial hazards, under construction over an eroding bank in Stowe, Vermont.



Over time, river meanders in valley bottoms tend to develop longer, more curved paths.

move around a lot. However, the rough length and slope of the river and its meanders will be fairly stable.[21]

The process of meandering is affected enormously by human activity. If a channel has down-cut and is now widening by undercutting an armored embankment, as described above in the section on down-cutting, it brings to this process the full power of a river in a confined, straightened channel. It is likely to be able to cause considerable erosion very quickly. Even regular daily flows may have the power to amplify a newly forming meander. Upstream activity can also have a significant impact. If the river has been confined and straightened upstream, it will have increased velocity and power coming into a meander. Again, erosion happens much more quickly (see photo from Ch. I of re-claimed meander straight through a road, p. 12).

In contrast, if people have conserved upstream floodplains and provided rivers the room to meander and braid, then the power of the river coming down river will be reduced.

Also, vegetation along river banks and woody debris in and beside the channel can make a big difference to the rate of erosion and channel migration. Strong root systems help protect and hold the soil and stream banks, while tree cover can reduce the force of precipitation. Woody debris in the channel can divert flow away from banks, and capture sediment. However, if people have cleared vegetation from the stream banks or removed all the wood from the channel, the soils are likely to erode more rapidly.[22]

Key Insight #15:
Vegetation and woody debris in the channel and on stream banks can slow river erosion.

Scour Holes Around Fixed Infrastructure

The third predictable pattern of channel change involves the creation of scours. When the flow of a river encounters an immovable object in its path, the force of the water is often diverted down, or sometimes to the side. This causes scour – that is, the intense erosion of sediments in a particular place that creates sudden deeper spots, or holes. Bridge abutments, large boulders, trees, culverts – any of these that are directly within the path of a river's flow are likely to create scour. Scour is often the secondary, unanticipated negative effect of our efforts to secure the location of a structure without regard to river patterns. It is often damaging because it can undermine the structures we have built, and because it can cause abrupt changes in depth of the channel that aquatic organisms may not be able to navigate.

Key Insight #16:
When we place fixed objects and structures in a river's path, we may create scour and damaging erosion either beside or underneath. This can undermine buildings and infrastructure, as well as habitat connections for aquatic organisms.

Toward River-Smart River and Land Management

These sixteen key insights about river flood hazards that come from the science of fluvial geomorphology lead to some principles for river-smart river and land management.[23]

The most fundamental management principle is: **We cannot stop river floods, but by managing rivers and riverside lands differently, accommodating their dynamic movements and interactions with the landscape, we can reduce their destructive force and keep our communities safe.**

The most important lesson for on-the-ground management is that we need to allow rivers to move.[24] We need to accept that when rivers flood, they move fast and with considerable force, and with large volumes of water, sediment and debris. First, as much as possible, we need to allow rivers to flood onto their floodplains. This allows flooding rivers to dissipate the energy and volume, reduce their veloc-

ity, and deposit nutrient-rich sediments.[25] Second, rivers need to meander and braid. This reduces their slope and therefore their velocity and destructive force. It also allows sediment and woody debris to be deposited along meanders and braids, where these deposits maintain rivers and renew habitat, rather than in giant accumulations that can damage lands, bridges and roads.

To give rivers room to move, we should keep our buildings, roads, structures and other investments out of their way wherever possible. We should remove berms and levees where we can, and restrict development on floodplain lands and river meander corridors, or what Vermont calls "river corridors" (see Example 13, p. 58). We can use a wide range of management tools, including outreach, planning, funding support, incentives, ordinances, conservation, easements, and buy-outs (see Recommendations, Chapter IV).

If budgets allow, there can be more active design work in streams, rivers and riverside landscapes.[26] However, giving rivers the time and space to produce their own restored channels and landscapes is often the simplest and least expensive option, and thus is the emphasis for this report.

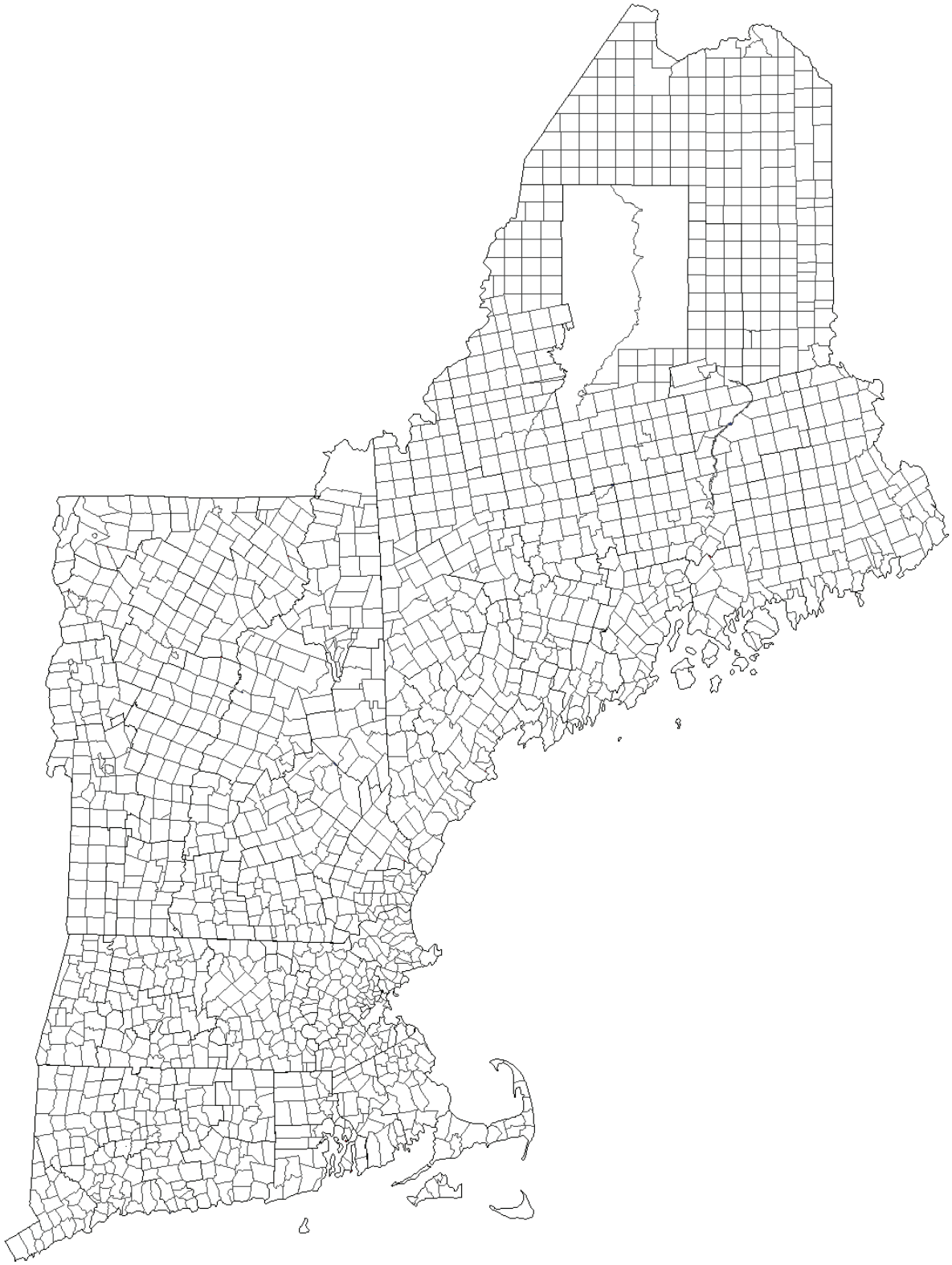
In some cases, we have to protect and armor narrow straightened channels – many New England towns were built right up against rivers, and in the region's steep valleys it may be financially impractical to move roads. When we protect and armor river channels, however, we should do so with caution and forethought, for we will be displacing force, volume, and sediment – whether to the side, to the stream bed, or downstream. We need to think at watershed scale, realizing that what we do in one location in a river system affects the risk of hazard faced in another, and what we do in many locations can dramatically increase or decrease damage in the next river flood. In rivers and watersheds where numerous sites must be armored, it may be important to find other, upstream places in the watershed where the river can be given room to spread out, to lessen impacts on vulnerable areas downstream.

Important Science and Management Lessons for River-Smart New England Communities

There are three key science and management lessons to take from this chapter about how to help New England communities become river-smart.

New England community officials, staff, landowners and residents, as well as the people working in and around New England communities, should:

1. **Understand and apply the science of river dynamics and its key insights on river floods–** both in general, and in relation to specific locations of concern and opportunity.
2. **As much as possible, find ways to give rivers room to move–** to carry and deposit water, sediment and debris, to flood floodplains, and to meander and braid.
3. **When armoring stream banks or deepening channels is unavoidable, mitigate this** so as to reduce unintended consequences of erosion and deposition that will be displaced elsewhere.



There are over 1500 municipalities in New England. Each has important authority over land use, and most have a strong tradition of independence. These are great strengths but pose a challenge to federal and state agencies that want to help New England communities become river-smart. Many small rural communities also have limited staff, funding and expertise.

III. The Challenge of River-Smart Governance in New England Communities: Lessons for Policy

In the previous chapter, the science of fluvial geomorphology led us to general management lessons. However, it is more difficult to step directly from general management lessons to practical methods for implementing those lessons, and the kinds of policies that might support them.

The key question for this chapter and the next is: What kinds of federal and state policies and programs could most help New England communities to become river-smart – while still being feasible, given the challenges of legislative and regulatory change, and limited fiscal resources?

To answer this question, the UMass River-Smart project worked from 2012 to 2015 to investigate three subjects: New England communities' needs; current major federal and state policies and programs on which we can build; and models of programs that seem to work particularly well. This chapter outlines and summarizes our findings. More details of our research methods, approach and findings are provided on our website. We also benefited from other researchers' work on similar topics.[27]

Small Towns with Big Responsibilities: What New England Communities Need and Want From Government Agencies and Programs, In Order to Become River-Smart

The starting place for understanding New England communities is to recognize some of their particular characteristics that present both strengths and challenges. Distinct from other U.S. states, New England states have weak or non-existent county governments. Also in contrast to other states with strong county systems, almost all land area in New England is part of a municipality of some kind. Thus, local government for the most part means municipal government, and local communities for the most part mean towns and cities.

New England also has a long history of strong local identity and independence. This independence has been codified in some of the New England states as home rule, and in others, is simply a deep commitment rooted in local and state culture.

Because of these factors, compared to communities in other states, New England communities have particularly strong responsibilities, authorities and independence.

Yet many of New England's municipalities have only a few dozen to a few hundred people – especially towns in the remote mountainous regions and rural valleys where communities are often most at risk of river flood damage.[28] Local governments are often operated largely by volunteers, and may have only one or two paid staff. Residents often come out to help one another in times of trouble, bringing great resources and resilience to their communities. In terms of local government's more mundane functions, however – whether maintaining roads and bridges, planning for future infrastructure or emergencies, administering land use or economic development policies – towns are often strapped for resources. The problem is exacerbated in some areas of rural New England, where localities have lost population and income over the last several decades as economies have shifted.

The weakness of counties in much of New England also means there is no local government that works routinely across a spatial area larger than a single municipality. This makes planning and mitigating for river floods more difficult, as often towns and cities need to coordinate their efforts up and down river in order to address both potential management actions and their consequences.

The great tradition of direct participatory democracy in New England can also make it more challenging for New England towns to respond quickly or effectively to the threats of river flood damage. In Town Meetings across the region, residents of small and medium-sized communities directly participate in decision making about issues like funding new bridges or passing new ordinances. We are rightly proud of this democratic heritage. However, Town Meeting is usually just once or twice a year in any given community, making quick decisions difficult. Moreover, because towns have so many "cooks" directly stirring the "broth" in our local governments, decision-making can be contentious. Funding decisions, and decisions about using municipal authority to limit or regulate private property, are often particularly difficult – yet these are sometimes decisions that are needed in order for towns to become river-smart.

From a local New England community's point of view, state and federal government policies and programs will be most helpful if they can recognize and work with this context. Municipal leaders and residents want government agencies and programs to respect their traditions, strengths and independence, while supporting them as they extend into new responsibilities, and while coordinating across towns and cities as needed.

How can we translate this general context and these general desires into more clearly articulated community needs, specific enough to begin to shape government agencies and programs? To focus our thinking, and to connect back to the previous chapter on river science and management, we can ask: What things do New England communities need in order to become river-smart?

Thoughtful officials, staff, landowners and residents across New England's towns and cities have begun to articulate answers to these questions. So have many government agency employees with experience working with communities. We talked to numerous people from both these groups. Based on this research, we identify the following core needs of New England communities to become river-smart. These inform the analysis in the rest of this chapter, and our five target recommendations in Chapter IV.

Core Needs of New England Communities for Becoming River-Smart

1. **Information, data, and training** on river science and river floods – for town leaders, staff and residents and for the many people and organizations, working in and around towns on structures and issues that affect resilience in river floods (this core need is addressed in Recommendations 1 and 4).

2. **Actions by non-municipal entities need to be river-smart** (e.g. road, bridge and utility repair; reservoir and dam management) (addressed in Recommendations 2 and 4).

3. **Coordination among public agencies, institutions and programs** so that they provide coherent, consistent guidance toward river-smart practice (addressed in all recommendations, especially Recommendation 5).

   - Sectors of public policy that need to be coordinated: flood hazards and emergencies, river and riparian ecosystems, fish and wildlife, water quality, infrastructure maintenance and repair, and land use, planning and development
   - Aspects of public policy that need to be coordinated so they promote river-smart practice across all sectors: on-the-ground projects; funding; insurance and incentives; data collection and dissemination; regulations; education and outreach programs; guidelines for best management practices

4. **Technical, administrative, and legal support** to assist towns and cities to take river-smart actions themselves, from problem identification to project implementation (addressed in all Recommendations, especially 2, 3 and 5).

   4a. **Support for towns and cities to conduct investigations and planning**

   - Facilitation of and guidance for local investigations and planning

- Facilitation of and guidance for multi-municipality watershed or regional planning
- Guidance on what is needed in different circumstances to prevent, reduce or mitigate river flood damage
- Incentives for river-smart planning

4b. Support for towns to acquire funding and build support to take action

- Help identifying sources of funding and support
- Help navigating regulations and funding requirements
- Help preparing grants, designs, etc.
- Easy-to-follow directions and templates, e.g. for funding applications or baseline studies
- Legal advice on municipal authority in relation to states, the federal government, individual property owners, and other towns and cities
- Help navigating and conducting community, property owner, and multi-municipality outreach and involvement
- Incentives for river-smart actions

4c. Support for design and implementation

- Easy-to-follow directions and templates, e.g. specifications for preferred bridge designs depending on different conditions
- Legal backing (if needed) to support local actions and measures
- Ongoing technical assistance as towns carry out their actions

5. **Ease in meeting regulatory and funding requirements** to undertake river-smart actions, so towns and cities can get timely approval and undertake river-smart actions without tremendous cost or effort (addressed in Recommendations 2, 3 and 5).

6. **Funding** to help pay for river-smart planning, preparations, actions, and follow-up (addressed in Recommendations 2, 3 and 5).

People of the town of Rochester, Vermont discuss ways to help those harmed by Tropical Storm Irene

Diverse Agencies and Programs with Some Common Constraints: Federal and State Agencies and Programs that Deal with Floods, Hazards, Rivers and Riverside Lands

There are many federal and state agencies and programs that are already working to meet New England's needs in relation to rivers and floods. To what extent do these agencies and programs provide and address what communities need in order to become river-smart? What constraints do they face? The following table outlines some of the most important federal programs and their ability to meet the over-all community needs listed above. In many cases, state programs extend or are able to fill some of the gaps left by federal policy and programs. We do not list all the relevant state policies and programs; they are too many and too diverse. A few model state efforts are profiled in the research section that follows, as well as in the recommendations in Chapter IV.

Table 1. Major Federal Agencies and Their Contributions to Help New England Communities Become River-smart

AGENCY OR PROGRAM	PROGRAM, ACTIVITY OR FUNCTION	COMMUNITY NEEDS MET (SEE PP. 26-27)	MAJOR CONTRIBUTION TO HELPING NEW ENGLAND COMMUNITIES BECOME RIVER-SMART	LIMITATIONS IN HELPING NEW ENGLAND COMMUNITIES BECOME RIVER-SMART
Federal Emergency Management Agency (FEMA) National Flood Insurance Program (NFIP)	Flood insurance maps	Information, data, and training (1)	Very useful data, readily usable. Huge amount of research done for communities and other agencies. Standardized data, mutually comprehensible across the country.	Focused on inundation - misses fluvial hazards from river floods. Maps not updated frequently, and smaller streams not mapped.
	FEMA flood mitigation guidelines and requirements	Support for towns to conduct investigations and planning (4a); Support for design and implementation (4c)	Extensive guidelines and clear incentive for property owners to reduce flood damage risk (can get insurance in flood hazard area, or under Community Rating System, can get discounted insurance).	Mainly focused on inundation, elevation - attention to fluvial hazards limited.
	Multi-hazard mitigation community planning	Support for towns and cities to conduct investigations and planning (4a)	Provides clear incentive for communities to adopt floodplain management ordinance or better community-scale mitigation measures. Encourages local input and participation. Communities may include fluvial hazards under Community Rating System (property owners in community can get insurance, or under Community Rating System, can get discounted insurance).	Mainly focused on inundation, elevation - attention to fluvial hazards limited. Requires individual local governments to adopt plans, inhibiting multi-town coordination.
FEMA Public Assistance Program - disaster recovery funding	Recovery funding	Funding (6); Ease in meeting regulatory and funding requirements (5)	Pays for recovery and repair of damaged public infrastructure. Environmental and other review is waived so repair can happen quickly. Can fund some mitigation.	Usually will not pay for upgrades, so vulnerable infrastructure is replicated. Usually requires 25% cost share, making this burden-some for small towns. Only available after declared emergency. Some guidance documents still suggest structural repairs without cautions that this may divert fluvial hazards to other locations.
FEMA Hazard Mitigation Grants Program (HMGP)	HMGP funding	Funding (6)	Provides moneys to reduce risk in advance of a flood. Encourages long-term perspective.	Competitive grant program so many applications will fail. Application and cost-share requirements are burdensome for small communities; sometimes prohibitively so. Discourages multi-municipality collaboration. Only available after declared emergency.
	Incentive for hazard mitigation planning	Support for towns to conduct investigations and planning (4a); Support for design and implementation (4c)	Provides clear incentive (eligibility for funding), and extensive and comprehensive guidelines for towns and communities to undertake hazard mitigation planning.	Hazard mitigation planning is burdensome and expensive for small towns and linked to uncertain funding, so the incentive is insufficient for many small communities to develop plans.

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AGENCY OR PROGRAM	PROGRAM, ACTIVITY OR FUNCTION	COMMUNITY NEEDS MET (SEE PP. 26-27)	MAJOR CONTRIBUTION TO HELPING NEW ENGLAND COMMUNITIES BECOME RIVER-SMART	LIMITATIONS IN HELPING NEW ENGLAND COMMUNITIES BECOME RIVER-SMART`
Community Development Block Grants for Disaster Recovery (CDBG-DR)		Funding (6); Ease in meeting regulatory and funding requirements (5)	Provides money directly to local communities and states. May be used very flexibly, even to help pay for cost share for federal grants. May come with requirements for building for resilience.	Requires a Presidentially declared emergency, and Congressional appropriations. Must be spent within two years. Use of funds limits eligibility to use other funds, even if complementary.
US Army Corps of Engineers (USACE)	Structural flood control - flood control dams, levees, etc.	Actions by non-municipal entities are river-smart (2)	Maintains system of flood control dams that reduce flood peaks, and levees that protect particular cities and towns. Recently, has moved toward allowing more natural flows including high flows (at levels that still protect public safety).	Reduces beneficial flooding, and alters natural seasonality of floods harming aquatic, floodplain and riparian species. Reduces sediment downstream of dams which can increase erosion. High maintenance costs. Reservoirs required permanent land acquisition. Protects only some tributaries plus mainstem rivers.
	General Permit	Support for design and implementation (4c)	Pushes and guides communities and property owners to build more resilient stream crossing infrastructure.	Limited enforcement for small projects; in past, inconsistently coordinated with state regulations.
	Environmental restoration programs	Actions by non-municipal entities are river-smart (2); Information, data, and training (1); Funding (5)	Can support green infrastructure, environmental restoration. High-level technical expertise on water, rivers, floods.	Large projects with 25% non-federal cost share, so generally inaccessible directly to small towns. Funds are limited nationally.
	General Investigation programs	Information, data, and training (1); Funding (6)	Can support new understandings, frameworks, prioritization of restoration, etc. USACE has high-level technical expertise on water, rivers, and floods.	Large projects, many with 50% non-federal cost share, so generally inaccessible directly to small towns.
	Silver Jackets	Coordination among public agencies, institutions and programs (3); Information, data and training (1)	Coordinates state and federal agencies in promoting flood resilience.	Limited staff and funding. Does not work directly with communities.
Federal Highway Administration Emergency Relief	Road and infrastructure construction and maintenance	Actions by non-municipal entities are river-smart (2)	Quick reconstruction to get roads and bridges functional again. Relatively consistent funding. Forward-thinking standards require and fund improvements that maintain structure for design life.	Moneys and projects not available directly to communities. Covers limited range of infrastructure. Does not take fluvial hazards systematically into consideration.

table continued next page

AGENCY OR PROGRAM	PROGRAM, ACTIVITY OR FUNCTION	COMMUNITY NEEDS MET (SEE PP. 26-27)	MAJOR CONTRIBUTION TO HELPING NEW ENGLAND COMMUNITIES BECOME RIVER-SMART	LIMITATIONS IN TO HELPING NEW ENGLAND COMMUNITIES BECOME RIVER-SMART
Environmental Protection Agency (EPA), US Fish & Wildlife (USFW), National Marine Fisheries Service (NMFS)	Regulations (e.g. Clean Water Act, Endangered Species Act) and recovery plans	Support for towns and cities to conduct investigations and planning (4a); Support for design and implementation (4c)	Regulations for water quality and species guide communities and landowners to protect streamside or riparian buffers, floodplains in ways that help river flood resilience.	Environmental goals not always well integrated with river flood public safety measures; sometimes these promote static, armored streams which can undermine rivers' ability to move and dissipate flood energy and volume.
	Funding, often through recovery plans	Funding (6); Support for towns and cities to acquire funding and build support to take action (4b)	Funding available to protect river functions, spaces, and connectivity in ways that can help reduce river flood volume, power, and damage.	
Natural Resources Conservation Service (NRCS)	Environmental Quality Incentive Program (EQIP), Emergency Watershed Program (EWP),and others	Support for towns and cities to conduct investigations and planning (4a); Support for towns and cities to acquire funding and build support to take action (4b); Support for design and implementation (4c); Funding (6)	Works closely with communities and landowners to help them improve lands and infrastructure. Provides technical assistance, guidance and funding as one package, assisting from start to end of project.	Funding programs have specific requirements that limit range of projects. Broader goal is usually to protect land, so some projects armor streams, which can undermine rivers' ability to move and dissipate flood energy and volume.
Federal Energy Regulatory Commission (FERC)	Hydropower licensing, compliance, safety & inspections	Actions by non-municipal entities are river-smart (2); Coordination among public agencies, institutions and programs (3); Funding (6)	Requires nonfederal dam owners to coordinate with federal dam managers and with federal, state and regional emergency responders in planning and executing emergency response if dam failures might cause significant property damage or loss of life. Encourages dam owners to include local communities in practice exercises. FERC can also require nonfederal dam owners to manage dams, reservoirs, and adjacent lands during regular operations to make fluctuations in river levels less rapid, and/or can require protection of floodplains and streamside riparian areas. The licensing process is participatory and encourages multi-party settlements that can creatively address different needs. Settlements may include funds that states and communities can use for river-smart actions.	Emergency Action Plans focus mainly on risk of dam failure; there is limited attention to other risks such as releases before, during or after high rain events. Vulnerability assessments focus on inundation hazards, not fluvial hazards. Communication and coordination prioritize federal, state and regional agencies and emergency response; coordination with communities is often indirect (through FEMA or states) and not as well developed. Dams alter river processes and functions, interfere with connectivity, and may prevent natural channel adjustments; these effects are seldom fully mitigated.

Common Gaps and Limitations of Federal Policy in Helping New England Municipalities Become River-Smart

As Table 1 shows, a wide array of federal agencies offer enormously helpful resources that contribute, or can contribute, to helping New England towns and cities become river-smart. However, they also leave some common gaps and limitations:

- Flood-related federal policies focus mainly on inundation, and do not adequately help municipalities prepare or mitigate for fluvial hazards
- Some programs still promote or facilitate old solutions – same-size structures or armoring streams, for example - that can increase long-term and downstream hazards
- Funding and application requirements are often burdensome for small communities
- Many agencies have limited staff and support may be available only after declared emergencies, and/or only on a competitive and short-term basis
- Programs may not be directly available to municipalities
- Different programs are often poorly integrated, and sometimes conflict
- Few programs facilitate multi-town collaboration in the same watershed or region; some even hinder this coordination

Challenges and Constraints Faced by Federal and State Government Agencies and Programs

What policies and actions might be able to fill in these gaps and help New England towns and cities become river-smart? Before answering this question, it is important to understand that, like New England towns, federal and state government agencies have their own particular context, constraints, and challenges.

The most over-arching constraint is that government agencies are taxpayer-funded (sometimes partly fee-funded) and their resources are finite. Indeed, budgets in many cases have decreased in the last decade or two. The lack of county governments and the small size of many New England towns amplify this problem as federal and state governments work with over 1,500 local governments across the six New England states.

A second constraint is that agencies and programs are authorized by Congress or state legislatures to do specific tasks and to fulfill particular goals. They are also guided by their own rule-making and funding sources. These direct and limit an agency's use of its funds, staff, and resources. Among the tasks that have not been prioritized by legislators and regulators in recent years is long-range and large-scale cross-watershed planning, even though it would help communities to prepare for river floods.

Third, some technical approaches and systems of administration can become constraining. Among those that cause problems for flood readiness today are a definition of flood hazard areas that focuses only on inundation hazards (see Example 2, p. 16), and a terminology of "100-year floods" that have made people think floods are uncommon (see p. 12).

Finally, there are broader trends and pressures that shape and constrain government programs. In recent years, one key trend has been to require potential recipients of government aid to compete for that aid. This is done in the name of efficiency and cost-effectiveness but it can have an unintended exclusionary effect. Small towns often simply cannot muster the time, funds and expertise to prepare high-quality grant applications or requests for assistance. Meantime, many government agencies and programs are themselves now running on grant funds. For municipalities this means that a program that assists them one year as they start planning a project may be gone by the time they are ready to implement the project. It may also mean that fewer agency staff have the long-term tenure that enables them to get to know many communities well. Grant funding also means agencies often have less ability to respond to new and unexpected community needs.

Government agency staff may understand these problems, and yet feel they have no easy way to fix them. How do we move forward?

Moving Forward: Harnessing Government Commitment to Improve Agencies and Programs

To begin, it is important to recognize that, despite some real limitations and constraints, there are many government programs and policies at all levels of government in New England that are helping New England communities to prepare and mitigate for river floods. Lawmakers at all levels have appropriated funds for a variety of programs because they recognize these problems are real and solutions are needed. Moreover, there has been more willingness to appropriate increased funds and improve policies since Tropical Storm Irene hit the region.

Our call for policy change needs to be greater than a demand for more money, more programs. Rather, money and programs should more successfully reach and meet the needs of New England communities. In many cases, becoming river-smart will be more successful and require less cost in the long run if, rather than maintaining control structures and funding myriad restoration and mitigation programs, we can understand and respect rivers well enough to avoid putting new development and infrastructure in harm's way, and can allow rivers to recover their natural methods of flood management by using their floodplains and meanders.

We need some good models.

Models of Helping Communities Become River-Smart, and Lessons for Policy and Practice

Between 2012 and 2015, the UMass RiverSmart project investigated seven institutions – a range of organized groups and programs – that have been particularly successful in helping New England to become more river-smart.[29]

Each case study institution had its own purpose, goals and resources, and each had different strengths and contributions. Our method was not to compare them, but to learn from all of them. We identified the strategies that each modeled, and strove to detail their most important model programs. These lessons were used to build our five target recommendations (see chapter IV). We also profile key programs and contributions of several of the institutions in pull-out Examples in this report. Our findings and their contribution to this report are summarized in Table 2.

More details of our research and research findings are available on our website, https://extension.umass.edu/riversmart/.

Table 2. Case Studies Investigated as Successful Examples of Efforts to Become River-Smart

INSTITUTION (WEB PAGE)	KIND OF INSTITUTION	FUNCTION / GOAL RELATED TO RIVER-SMART COMMUNITIES	COMMUNITY NEEDS MET PP. 26-27)	RECOMMEN-DATION #	EXAMPLE #
Vermont Rivers Program http://www.anr.state.vt.us/dec/waterq/rivers.htm	State program	Goals are to support flood resilience, public safety, and ecological connectivity across and along rivers and floodplains. Provides river and floodplain assessments, including fluvial hazard risk and delineation of river corridors. Provides technical, regulatory and financial assistance to evaluate and mitigate activities in rivers, streams, floodplains, and river corridors. Offers training to transportation workers and others.	1, 2, 3, 4 (a, b, c), 5, 6.	1, 2, 3, 4, 5	3, 4, 6, 7, 9, 10, 11, 12, 13,
New Hampshire Post-Incident Recovery Response Team (PIRRT) / New Hampshire Silver Jackets http://silverjackets.nfrmp.us/State-Teams/New-Hampshire	Formal inter-agency partnership	Coordinates and informs state and federal river and flood activities in New Hampshire to improve consistency and river-smart practice. Goals are to help New Hampshire better prepare, mitigate, and recover from flood events and to reduce flood risk.	3	3	
Natural Resources Conservation Service (NRCS): Environmental Quality Incen - tive Program (EQIP), Emergency Watershed Protection (EWP) and other programs http://www.nrcs.usda.gov/	Federal agency with state offices, linked to substate Conservation Districts	Provides technical and financial assistance to plan and implement conservation practices on private agricultural and forest lands (EQIP). Many of these practices can restore rivers' ability to move and dissipate force and volume. Also helps communities relieve imminent hazards caused by natural disasters (EWP) - e.g. can help communities replace inadequate, failing culverts with ones that are more appropriately sized and shaped. NRCS's EWP is available even when there is not federal or state disaster declaration.	4 (a, b, c) 5, 6	2, 3, 5	11
Franklin Regional Council of Governments (FRCOG): Natural Resources Planning, Emergency Preparedness, and other programs http://frcog.org/	Regional agency (substate / multi-municipality)	Goals are to promote opportunity, resilience and sustainability in the 26 towns of Franklin County, western Massachusetts. River-smart goals include promoting sustainable land use practices, conserving watershed and water resources, facilitating emergency preparedness, and raising public awareness about the value of natural "green infrastructure." Works with federal and state agencies, and local communities, to acquire funding, provide technical support for planning, assessments, and project implementation, and facilitate multi-town coordination.	1, 2, 3, 4 (a, b, c), 5	3, 4, 5	19
Creating Resilient Communities	Informal collabora-tion among communities, agencies, nonprofit conservation groups	Goal is to coordinate among different towns, groups, and individuals to coordinate efforts and seek additional resources for river-smart recovery, assessment, mitigation, and prepara-tion. An ad hoc group of community leaders, government agency representatives, conservation group leaders, and university researchers and extension faculty.	3, 4(a, b)	3, 4, 5	
White River Partnership http://whiteriverpartner - ship.org/	Nonprofit conservation group	Goal is to bring people and communities together to improve the long-term health of the White River watershed. Works with state, federal and regional agencies to support landowners, communities and volunteers to acquire funding, conduct assessments, and carry out on-the-ground flood resilience, water quality and watershed improvement projects.	1, 2, 3, 4 (a, b, c)	3, 4, 5	21
North Atlantic Aquatic Connectivity Collaborative https://www.streamcontinui - ty.org/	Network among individuals in universities, conservation groups, government agencies	In order to support aquatic connectivity, has networked across universities, conservation groups, and government agencies, to develop common protocols for assessing and improving road-stream crossings. Also provides trainings and has developed a database of crossings.	1, 2, 3	2, 4	8, 9

Governance, Policy and Institutional Lessons for River-Smart New England Communities

To summarize this chapter, there are four key governance, policy and institutional lessons to help New England communities become river-smart:

1. **New England towns and cities have needs that are distinct from local governments in other parts of the country, because of their particularly strong responsibilities, authorities and independence. Yet small remote towns that often bear the brunt of river flood damage generally have limited staff, funding, and expertise. These strengths and challenges result in identifiable specific needs:**
   1) Information, data, and training on river science and river floods
   2) Actions by non-municipal entities need to be river-smart
   3) Coordination among public agencies, institutions and programs
   4) Technical, administrative, and legal support
      4a) Support for towns and cities to conduct investigations and planning
      4b) Support for towns to acquire funding and build support to take action
      4c) Support for design and implementation
   5) Ease in meeting regulatory and funding requirements to undertake river-smart actions
   6) Funding

Federal and state policies, programs and staff that aim to help New England communities need to recognize and support these peculiar strengths, challenges and needs.

2. **Federal agencies provide an enormous range of resources and contributions to help New England communities become river-smart, but there remain gaps in their ability to meet New England communities' flood resilience needs. State agencies and programs fill some but not all of these gaps. Among the most common:**
   - Flood-related policies focus mainly on inundation, not fluvial hazards
   - Funding requirements are burdensome for small communities
   - Many agencies have limited staff and funding; programs may not be directly available to municipalities; and different programs are often poorly integrated, and sometimes even conflicting

3. **Federal and state agencies face four general, pervasive constraints**
   - Limited budgets
   - Limited authorities
   - Constraining technical approaches
   - Unreliability and exclusion when these are unintended consequences of competitive funding models

Rather than criticizing government officials and agencies, we should help guide them to spend their taxpayer-provided moneys, and orient their programs in ways that reach and meet the needs of New England communities more successfully.

4. **There are numerous organizations in New England that have been particularly successful in helping New England communities to become more river-smart.** These can and should be investigated for a range of models and lessons. Many of these are included in our recommendations and examples in Chapter IV.

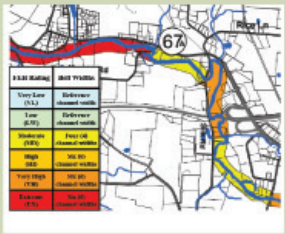
IV. Target Recommendations for Federal and State Policy

Based on the historical, scientific, and policy background covered in Chapters I-III, we developed five target recommendations for policy change in New England. Our recommendations are oriented to federal and state governments, but we do not identify what agency or state needs to do what. Rather we aim to offer guidelines and examples so different states and agencies can adopt these recommendations while creating their own particular approach.

The five recommendations cover three categories of ways to help communities become river-smart.

Information about river and stream hazards that communities need to be River-smart

Target Recommendation #1:
Develop Fluvial Hazard Assessments



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On-the-ground actions that can help communities become river-smart

Target Recommendation #2:
Upgrade Vulnerable Stream Crossing Infrastructure

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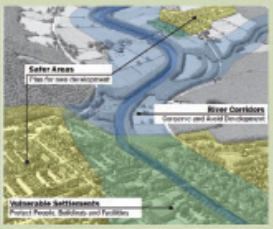
Target Recommendation #3:
Support River-Smart Planning and Mitigation



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Outreach and coordination that communities need, to make river-smart actions achievable and cost-effective

Target Recommendation #4:
Provide Outreach and Training on River Dynamics and River-Smart Practice

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Target Recommendation #5:
Designate, Recognize and Support River-Smart Regional Intermediaries

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Summary of Target Recommendation #1:

Develop Fluvial Hazard Assessments

Municipal need:

Easy-to-use, place-specific data about local and regional fluvial hazards.
(See page 37).

Municipal need elements:

Easily accessible data and information on fluvial hazards that may affect municipal residents, property owners, buildings, or infrastructure.

Recommendation:

Develop and implement fluvial hazard assessment, mapping, and user access systems across the New England states.
(See page 38).

Recommendation elements:

Develop and implement fluvial hazard assessment protocols, systems for implementation, and user-friendly maps and information portals.

Fluvial erosion does not simply immerse areas in water. It cuts away stream banks and stream beds, abruptly moving dirt, rocks, trees, and other material.

Target Recommendation #1: Develop Fluvial Hazard Assessments

Background

In many towns, long-time residents know places where there have been repeated road, stream crossing, or riverbank failures during river flood events. However, often there is not a clear understanding of why these failures happened in a particular place over and over again. When the entire river system is considered as a whole, these sites of repeated failure may be recognized as locations where the stream is confined to a narrow area, where the stream channel makes a sharp turn, or where the stream channel suddenly becomes wider and flatter. While longtime locals may know the where if not the why of common river flood hazard areas, relative newcomers, repair and assistance technicians, and developers may know nothing about these hazards at all.

Fluvial hazard assessments help identify locations where there may be damage of this sort in future floods. These are the most exhaustive form of stream hazard assessment. They can quantify the potential for erosion and deposition, in addition to inundation, with a high degree of accuracy, both locally, and across an entire state or region.

This kind of information is critical because it can help landowners, developers, municipal officials, transportation and public works staff, planners, and others, to anticipate and prepare for these possible hazards. With this information, city and town staff and others working in areas that affect municipalities can design infrastructure and locate valuable property out of harm's way, while planning for productive recreational or agricultural uses of flood-prone land. People can be safer, and their investments more secure, while living in harmony with their rivers. Without fluvial hazard information, though, we continue "business as usual" – building structures and roads in areas that are likely to be undermined by the natural movements and changes of rivers through time.

Fluvial hazard assessments identify locations of hazards, and evaluate the level of risk. They illuminate two broad types of hazards: erosion and deposition (see Chapter 2 for more on river dynamics).

- ***Fluvial erosion*** occurs when the power of a moving river is greater than the strength of the bed, bank and/or road or culvert materials. In these areas, the river in future floods may break through land or structures. Sections of stream banks may collapse, bridges or other stream-crossing structures may wash out, or rivers may carve new meanders or channels (see photos pp. 9, 11, 12, 14, 16, 21, 36).
- ***Fluvial deposition*** occurs in locations where the power of moving floodwaters is suddenly reduced, for example when a very powerful stream confined in a narrow valley runs into a valley that opens up and flattens out. In these areas, large amounts of sediment and debris may be deposited by a river flood (see photos pp. 9, 10).

Once specific areas are assessed, assessment information can be put on maps. A map of fluvial hazards shows areas of high, moderate, and low risk of erosion or deposition. It can show a municipal leader or a road crew whether a planned work site is at risk of fluvial damage. It can indicate interrelated locations up and down a river, where, for example, erosion upriver might cause greater deposition downstream.

Municipal need #1: Easy-to-use, place-specific data about local and regional fluvial hazards

Municipal Need #1 Elements: Easily accessible data and information on fluvial hazards that may affect municipal residents, property owners, buildings, or infrastructure

Community officials, staff, road crews, property owners and residents need consistent information in a systematic format to determine where erosion and deposition hazards are greatest, and where these exist in the context of the river system as a whole.

They also need to be able to access and understand this information. Maps are particularly user-friendly tools. Yet information about fluvial hazards is not available in FEMA flood hazard maps, which is where most people look to find out what areas of land may be vulnerable to flood damage. They have information only on likely areas of inundation (see Example 2: Inundation Versus Fluvial Hazards, p. 16).

Community leaders and members need maps with information about fluvial hazards that are just as accessible and comprehensible as FEMA flood hazard maps. They need this so they can make responsible and resilient land use management decisions, and develop river-smart plans for infrastructure and development. It is also helpful for grant or permit applications.

Recommendation #1: Develop and implement fluvial hazard assessment, mapping, and user access systems across the New England states

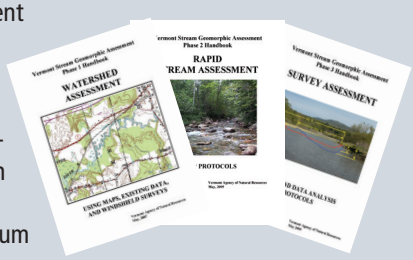
Recommendation #1 Elements: Develop and implement fluvial hazard assessment protocols, systems for implementation, and user-friendly maps and information portals

New England is lucky to have an excellent model of a fluvial hazard assessment system. Vermont has a widely-used, well-developed fluvial hazard assessment protocol and a number of map products that communities can access in a variety of ways and places (see Example 3: A Model for All New England). New Hampshire also has a similar protocol though it has been less used, and is also developing similar maps.

The other states and/or a federal agency should follow Vermont's lead to develop and implement fluvial hazard assessment systems. Each state may want to develop its own particular approach, due to differences in local topography, geology, political and fiscal context, and

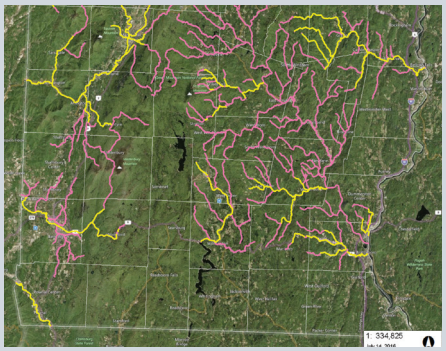
Example 3. A Model for All New England: Vermont's Stream Geomorphic Assessment System

Vermont is the leader among New England states in developing a fluvial hazard assessment system. The Vermont Rivers Program, working together with the Fisheries Division and the Vermont Geological Survey (all within the Agency of Natural Resources), developed a series of geomorphic assessment protocols for the state starting in the early 2000s. By now the state's protocols are well tested and refined, and assessments have been carried out in over 8,000 miles of streams - including virtually all the medium to large streams in the state.



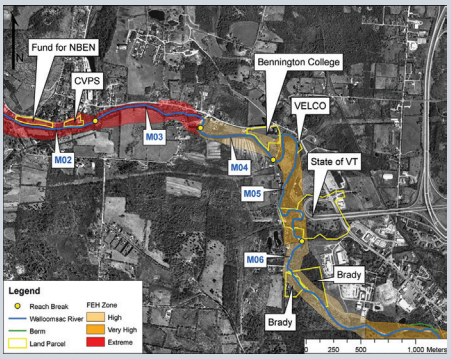
Assessments are done in three phases, following three protocol handbooks. Each requires greater time and effort and provides finer detail. Phase 1 is a watershed assessment based on existing maps and data and "windshield surveys"; Phase 2 is a rapid field assessment; and Phase 3 is a survey assessment using field surveying techniques and quantitative studies.

Towns, regional commissions, nonprofit agencies and others can take the initiative in conducting geomorphic assessments. The state offers some funding for assessments, and several federal agencies contribute as well.



Stream geomorphic assessment status in southern Vermont, as shown by the Vermont Natural Resources Atlas. Here, pink = Phase 1 complete; Yellow = Phases 1 and 2 complete.

Once assessments are completed, data are published in local or regional watershed assessments. They are also available online through the Vermont Natural Resources Atlas. Maps allow easy, user-friendly understanding of fluvial hazard risks. More detailed data is available through published documents.



This 2007 assessment of the Walloomsac River identified fluvial erosion hazard (FEH) zones and also areas where streamside lands might be conserved to allow river movement and flooding, reducing flood damage. These and other Vermont stream geomorphic assessments are on line at: https://anrweb.vt.gov/DEC/SGA/finalReports.aspx.

river and land management policies. Alternatively, they could borrow from Vermont, as New Hampshire has, so as not to replicate work unnecessarily. A third option would be to have a federal agency develop a fluvial hazard assessment system that could be used by all the New England states.

To create its own systems, or to adapt Vermont's for its own circumstances, a state or a federal agency must commit to providing the necessary resources to develop and conduct assessments, and make them available to communities.

To develop and implement fluvial hazard assessment systems, the essential steps are:

Develop assessment protocols

Assessment protocols should include both computer- and field-based analysis of the physical conditions of local rivers and streams. Whether uniform or distinct across the New England states, common elements should include:

- Characterization of the physical processes that govern streams
- An understanding of how human activities affect these processes over time
- An understanding of the sensitivities of these physical processes to future changes
- Types and locations of physical processes that create erosion, deposition and flood hazard risks to towns
- The relationships between physical processes and aquatic, riparian and floodplain habitats

Over time, New England should move toward a mutually comprehensible or unified assessment system so data can easily be shared across state lines.

Develop systems and support to conduct the assessments across each state's rivers and streams

Once protocols are developed, the work must be done to complete the assessments. Different states may choose to do this in different ways. Some may choose to allow towns and regional agencies to take the lead in initiating an assessment, and support them with funding to hire private consulting agencies to do the assessments. A state or federal agency could require or provide incentives for this work to be done. This has been Vermont's approach. One advantage is that it allows communities to take the lead, and move forward at their own pace in assessments. On the other hand, New England states with large rural-urban divides may choose to conduct assessments in-house to avoid favoring towns or cities that are able to devote increased amounts of resources to the process.

Develop and support widely accessible, user-friendly maps and information portals

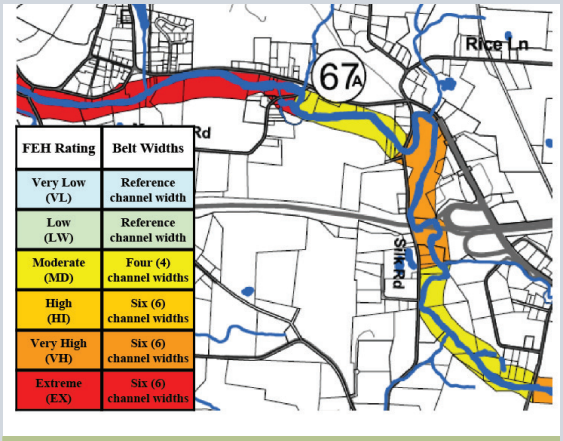
Assessments should produce maps with easy-to-understand designations of high, medium and low risk of fluvial erosion and deposition. There should also be web portals that include educational and training materials along with maps and other town-specific or river-specific data and planning information and recommendations.

One way to make fluvial hazard assessment summaries as widely accessible as possible would be to have them marked on FEMA Flood Insurance Rate Maps, though there are reasons to be cautious about this. This option should be explored, as Vermont is doing with FEMA in the town of Bennington (see Example 4: Could Fluvial Hazards Be Put on Already Widely Used Maps Such as FEMA Flood Hazard Maps?, p. 40).

Develop a quality control system

A quality control system should cross-check data inputs from varying sources to check formatting and flag inconsistencies with other data.

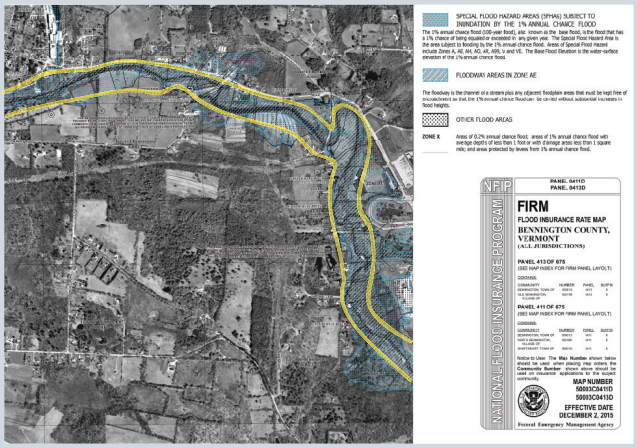
Example 4. Could Fluvial Hazards Be Put on Already Widely Used Maps Such as FEMA Flood Hazard Maps?



FEH Rating	Belt Widths
Very Low (VL)	Reference channel width
Low (LW)	Reference channel width
Moderate (MD)	Four (4) channel widths
High (HI)	Six (6) channel widths
Very High (VH)	Six (6) channel widths
Extreme (EX)	Six (6) channel widths

Fluvial Erosion Hazard Areas in Bennington, VT.

Stream Geomorphic Sensitivity in Bennington, VT, based on a Vermont stream geomorphic assessment completed in 2007. Higher geomorphic sensitivity means streams are more prone to erode or have their channels adjust and move.



FEMA Flood Insurance Rate Map for Bennington, VT, December 2015, with close-up below. The blue marks the area that would be inundated by a 1% annual chance flood (100-year flood). There is a harder-to-see area of black dots that marks the 0.2% annual chance flood (500-year flood). The Bennington maps are unique in also having a border marking a Fluvial Erosion Hazard zone (we have outlined in yellow). This overlay shows clearly that some areas outside the 1% annual chance inundation zone are nonetheless highly sensitive to geomorphic change.

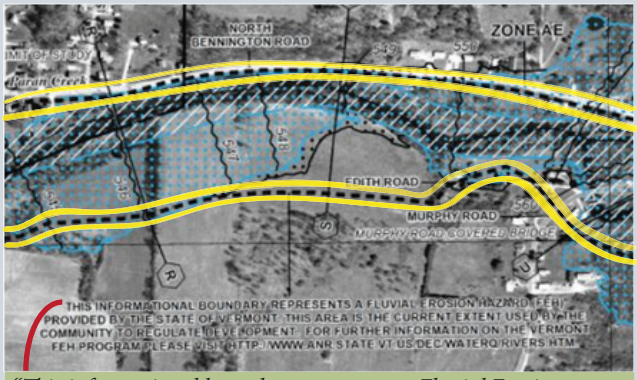
Once fluvial erosion hazard (FEH) assessments are developed, it is crucial that they be communicated in ways that are understandable and useful. One of the ways they might be most broadly and readily communicated and understood would be by adding them to FEMA flood hazard maps.

To test the technical and communication potential of showing fluvial hazard zones on FEMA flood maps, the state of Vermont, the town of Bennington, and FEMA worked together to try out the possibilities of overlaying maps in this way.

In 2009, Bennington had adopted a Fluvial Erosion Hazard Area Overlay District (FEH District) to regulate development in areas that might be subject to fluvial hazards. The area encompasses zones of high geomorphic sensitivity as revealed in a stream geomorphic assessment in 2007.

This FEH District was delineated on new FEMA flood maps created in December 2015.

Adding fluvial hazard zones to FEMA insurance maps bears caution. Some people are understandably concerned that there may be potential implications for insurance rates and property values, for properties that are outside current FEMA hazard delineation but inside fluvial erosion hazard zones. In these maps, the Fluvial Erosion Hazard district was marked specifically as only an "informational" boundary.



"This informational boundary represents a Fluvial Erosion Hazard (FEH) provided by the State of Vermont. This area is the current extent used by the community to regulate development."

Summary of Target Recommendation #2:

Upgrade Vulnerable Stream Crossing Infrastructure

Municipal need:
Upgrade vulnerable and damaged stream crossings to reduce future damage
(See page 42).

Recommendation:
Support upgrades of vulnerable stream crossings across the six New England states
(See page 48).

Municipal need elements:	Recommendation elements:
a) Standards for stream crossings that ensure that crossing infrastructure is resilient to river floods	a) Improve stream crossing regulatory standards to support upgrades, be consistent across agencies, and allow site-specific flexibility (well under way in New England)
b) Simple permitting and funding processes and requirements to replace vulnerable and damaged crossings quickly and efficiently	b) Streamline permit and funding processes and requirements, and incentivize replacing vulnerable and damaged crossings with upgrades
c) Easy-to-follow guidelines for upgraded crossings that are likely to win approval and funding	c) Develop and make available easy-to-follow design templates and guidelines for upgraded crossings which will receive quick permitting and funding review and high likelihood of approval
d) Data and information about vulnerable stream crossings, and opportunities to share communities' knowledge	d) Develop and support an accessible inventory and database of stream crossings that identifies vulnerable crossings.
e) Financial help to plan and construct needed upgrades	e) Increase and diversify funding for stream crossing upgrades.

Target Recommendation #2: Upgrade Vulnerable Stream Crossing Infrastructure

Background

One of the best, most cost-effective, and least intrusive ways to reduce damage from river floods is surprisingly mundane: use more appropriately sized and designed pipes, bridges and conduits for stream crossings that are vulnerable to flood damage and failures. Stream crossings – places where streams have to go under roads or other infrastructure – tend to be chokepoints for water, sediment and debris. At crossings, streams run through a constructed opening, often a pipe called a culvert. Culverts pass normal volumes of water easily, but they are often too small or poorly shaped to accommodate the hugely elevated flows of water in a river flood, and they can get blocked up by sediment or debris even during moderate flows, or blockages can accumulate over time.

In a river flood, an overflowing river may back up behind a crossing that is too small or is blocked. It may flow over and around the crossing onto adjacent roads and property. Worse, it may undercut banks and abutments, potentially causing sudden and complete collapse.

To avoid these problems, inadequate culverts in vulnerable and damaged stream crossings must be replaced with appropriately sized and shaped, strategically placed, culverts and other conduits. Larger crossing infrastructure is often helpful to pass high volumes of sediment and debris, avoiding blockage or damaging overflow. Open-bottomed stream crossings are especially effective – they act simply as part of the river. If not open-bottomed, then the shape and surface of the stream bottom should be replicated as much as possible to simulate the stream shape, bed material, and dynamics of the adjacent stream upstream and downstream (see Example 5: Upgrading Stream Crossings, p. 43). Larger and open-bottomed stream crossings are more expensive in terms of up-front costs, but because they last longer and reduce future flood damage, they often save money over the long run (see Example 6: Upgrading Stream Crossings Often Lowers Long-Term Costs, Adds Many Benefits, p. 44).

Upgrading stream crossings provides other benefits as well. Some of the most significant are the ecological benefits, as upgraded crossings can provide safe, adequately sized, and appropriately shaped and textured migration corridors for fish and wildlife. They also allow a more natural and dynamic movement of sediment and debris, which allows for the continual renewal of quality habitat. These benefits reduce the need for more costly artificial breeding and habitat reconstruction later on (see Example 6: Upgrading Stream Crossings Often Lowers Long-Term Costs, Adds Many Benefits, p. 44).

Many municipal officials, transportation engineers and emergency personnel in New England know their communities would be much safer during river floods if they upgraded their vulnerable stream crossing infrastructure. However, at present most towns continue to have undersized culverts under most of their roads, and too often, when they do replace them, they replace them with the same size and kind of culverts. New England towns and cities still have five needs in order to be able to upgrade their vulnerable stream crossings and dramatically reduce their future flood damage.

Municipal need #2: Upgrade vulnerable and damaged stream crossings to reduce future damage

Municipal Need #2 Element a) Standards for stream crossings that ensure that crossing infrastructure is resilient to river floods

Municipalities need state and federal standards for stream crossings to guide them to build and maintain infrastructure that can withstand river floods. Unfortunately, regulatory standards for stream crossings have sometimes been part of the problem. Many of the culverts in our rivers and streams today were constructed based on past standards of "hydraulic design" – standards of water flow. The standards did not take into consideration the huge amount of

Example 5. Upgrading Stream Crossings

A double box culvert on Bronson Brook in Worthington, MA was long a barrier to fish due to a perched outlet, shallow water depths and excessive water velocities. It became clogged with debris during a large storm in August 2003, and failed catastrophically when it was overtopped with water and the fill around the culverts was eroded away. The stream dug a 14 ft. (4 m) wide rift between the road and the culverts.

This new crossing was installed in 2008 on Bronson Brook through a partnership of federal, state and non-profit agencies. It cost less than an in-kind replacement. During Irene, large wood and boulders passed beneath this fish-and-wildlife-passage-friendly structure without damaging it.

Traditional stream crossing infrastructure is often designed based only on how much water it should pass, with no attention to the need to pass sediment, debris, and aquatic organisms. Traditional stream crossings often have one or more of the following problems:

- Undersized – do not have the capacity to pass expectable volumes of water, sediment and debris
- Too shallow – aquatic organisms cannot safely pass
- "Perched"- hang inches or feet above the level of the stream bottom at the downstream end, making organism passage impossible and increasing chances of scour and erosion
- Unnatural bed materials – may be avoided by aquatic organisms, or may alter the natural flow of sediment, causing erosion elsewhere
- Poor positioning – changes the direction or speed of water flow to create scour or other problems

These kinds of problems frequently result in damaged or destroyed stream crossings during large flood events. Blocked culverts may flood lands and infrastructure behind and to the side of the stream crossing, or they may break suddenly, causing catastrophic damage downstream.

Old 7 foot pipe culvert. These types of culverts remain common in New England. In Vermont alone, 964 culverts were damaged, destroyed or blown-out during Tropical Storm Irene.

Upgraded stream crossings solve these problems by:

- Being appropriately sized to pass water, sediment and debris during high flows, and to span the stream and the banks so fish and wildlife can pass through
- Having a shape to support natural depths, speed, and direction of water flow
- Being open-bottomed or sunk into the streambed to prevent perching
- Having a natural streambed

(See Massachusetts Stream Crossings Handbook, www.mass.gov/eea/docs/dfg/der/pdf/stream-crossings-handbook.pdf, for more detail.)

Example 6. Upgrading Stream Crossings Often Lowers Long-Term Costs, Adds Many Benefits

It may seem that constructing an upgraded culvert for a stream crossing is necessarily more expensive than constructing one of the same size and shape. It is true that in the short term, upgraded crossings often cost more. They are often larger, and they require more care to ensure compatibility with the stream slope, bed, and flow. The materials for a larger culvert are more expensive, and the construction may involve a larger area. A more elaborate permit and design frequently add expense.

Yet despite all these costs, over the lifetime of an upgraded culvert, it often saves money. This is because it requires less maintenance, lasts longer, and reduces river flood damage from both large and small floods. It also brings a range of additional ecological and other benefits.

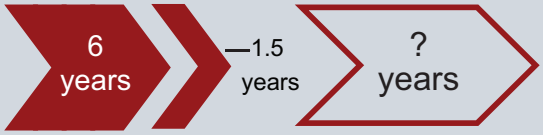
Two recent studies highlight these points. In 2015, the Massachusetts Division of Ecological Restoration compared the costs of replacing three culverts with same-size structures, versus upgrading the crossings to meet the new 2014 Massachusetts Stream Crossing Standards. The crossings would be maintained over 30 years. On average, over 30 years, the upgrade was 38% less expensive than the same-size replacement because many of the same-size structures needed repair or replacement once or more within their first 30 years. In many cases, upgraded crossings should last 50 years or more.

A 2013 study by The Nature Conservancy noted that long-term maintenance costs of smaller culverts will become more and more expensive, as extreme weather events increase in frequency with climate change.

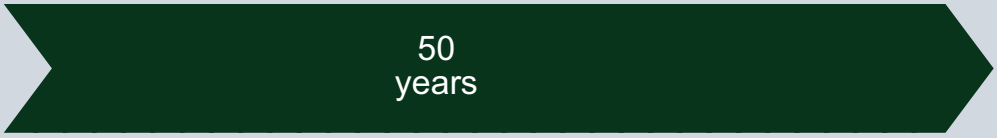
Both studies also highlighted an array of benefits of larger stream crossings that are not often included in cost-benefit analyses: healthier rivers and streams, enhanced river-related recreation, higher property values, improved safety and mobility, improved water quality, and, of course, reduced flood damage. Considering these longer-term costs and multiple benefits shows that upgrading stream crossing infrastructure is very cost-effective, generally saving money over the long run and adding a range of benefits.

In Becket, MA, the Walker Brook double-pipe culvert had to be replaced twice in 7.5 years, following major floods in 2005 and 2011. If the culverts need to be replaced at this same rate over the next 50 years, Becket will spend a total of $867,000 on culverts in just this one location.

If instead Becket invests in a more appropriately sized and shaped bridge-span crossing, the crossing will be more resilient to future river floods and should last 50 years or more. Aquatic organisms would also benefit. Total cost over 50 years under this scenario: $300,000-$400,000, much less than repeating the old-style culverts shown here and dealing with frequent replacements.



Cost of two replacements in 7.5 years: $130K. Cost to continue replacing at this rate: $867,000 over 50 years.



Cost of a Stream Continuity Crossing with a 50-year lifespan: $300-$400K

sediment and debris that a river carries when it is flooded. Also, old standards were often designed for medium-sized floods, even though very large floods are a regular part of the region's history and geography. Standards for stream crossings need to guide towns and cities to build crossings that can withstand high flows of water, sediment and debris.

Communities also need standards to be consistent across agencies. In many cases different agencies in a state (e.g. department of transportation and department of fish and wildlife) have distinct standards, and specific offices have contrasting enforcement practices. This inconsistency leads to confusion among municipal officials about which standards are necessary, as well as frustration at having to meet multiple regulatory mandates and paperwork. It also sometimes makes it harder for towns to get funding for crossing upgrades, as funders point to this regulatory inconsistency, and pay only for crossings built to lower standards (see Example 7: State Stream Crossing Standards Meet Federal Funding Requirements: How to Help Towns Not Get Stuck in the Middle, p. 46).

At the same time that towns and cities need regulatory consistency, though, they also need stream crossing standards to allow flexibility for site-specific considerations. For example, it may be inappropriate to build a large culvert on a tiny intermittent stream, and less possible in a highly urbanized area; on the other hand, it may be crucial on a small stream in a steep hill slope area where the chance of local flooding and erosion or blockage is high. Municipalities need regulations that can support and guide them to respond to differing conditions and needs, while clearly and consistently supporting upgrades of the most vulnerable crossings.

Municipal Need #2 Element b) Simple permitting and funding processes and requirements to replace vulnerable and damaged crossings quickly and efficiently

Unfortunately, the permit process and funding requirements in most states provide easier approval of same-size "in-kind" replacements (see Example 7: State Stream Crossing Standards Meet Federal Funding Requirements, p. 46). This is so for several reasons. When a road or bridge is washed out, permitting requirements are often waived, but only if the structure is replaced with the same kind. Required cost-benefit analyses generally look only at short-term, narrowly defined, and site-specific costs and benefits, and suggest that upgrades are not effective. Finally, funders will often not pay for the additional expense of upgrades, unless they are clearly required by all relevant state and local regulations.

These rules have perverse effects on public safety. Municipal decision makers often choose to replace damaged crossings with same-size crossing infrastructure, in order to reduce the time, complexity and cost of permit applications. Worse, towns and cities do not replace vulnerable, un-damaged crossings at all – they wait until crossings fail so they can be replaced without lengthy and expensive permitting and design approval processes. As a result, communities remain vulnerable to repeat damage in future river floods – and so do their downstream neighbors.

Towns need regulatory processes and funding requirements that expedite rather than discourage approval and funding of upgrades for damaged crossings vulnerable to repeat damage.

Municipal Need #2 Element c) Easy-to-follow guidelines for upgraded crossings that are likely to win approval and funding

Many municipal officials and staff find that although they understand the key parameters of stream crossing standards, using the standards to develop design plans remains complex and burdensome. They could move much faster and with more confidence toward upgrading stream crossings if they had a set of about ten template designs that would be appropriate under different circumstances, that would enable them to get an expedited review, and that would come with high likelihood of permit and funding approval.

Example 7. State Stream Crossing Standards Meet Federal Funding Requirements: How to Help Towns Not Get Stuck in the Middle

In some New England states, there are different standards for stream crossings among different agencies, or inconsistent or uncertain enforcement. This can be a problem for municipalities, because it may be unclear which standards they need to meet. Also, when municipalities choose to upgrade crossings, funders may provide moneys to meet only the lowest or the fully enforceable standards – and towns may end up having to foot the bill for the upgrade.

This happened to the town of Townshend, Vermont. After Irene, Townshend had several blown-out culverts. It upgraded to wider crossings and open-bottomed ones that were required by the recent 2010 Vermont state standards. Townshend then applied to FEMA for reimbursement.

However, FEMA declined to pay for the upgrades. FEMA is required by its rules to fund projects that meet applicable codes and standards. Under Vermont regulations in place at the time, towns did not have to report on the way their upgrades met the 2010 standards. FEMA ruled they were in effect discretionary.

The state of Vermont helped draft an appeal. FEMA ultimately reversed its decision and funded Townshend's upgraded culvert. But FEMA held firm that it could not pay for towns to upgrade to what it deemed to be discretionary standards. To meet FEMA's requirements, Vermont needed a more systematic solution. The state revised its culvert standards and permitting processes to make sure towns were required to report on their efforts to meet upgrading standards, so that the standards would be enforceable. It also made sure they were consistent across multiple state agencies and towns, including the Vermont Department of Transportation, Town Road and Bridge Standards, and the general state permit of the Agency of Natural Resources.

Townshend road crossing. The left-hand photo shows the crossing after Tropical Storm Irene. A wire with dangling posts - the remains of a guard rail - was all that was left of the road. The former crossing had an oval pipe ("plate arch") culvert which failed catastrophically. The new crossing, built to Vermont's 2010 standards, is on the right.

Municipal Need #2 Element d) Data and information about vulnerable stream crossings, and opportunities to share communities' knowledge

With thousands of stream crossings in each state, municipal officials, staff, landowners and residents need to know which crossings are priorities to upgrade to reduce future flood damage. Many town staff and residents have experience with at-risk crossings, or crossings that have failed multiple times. However, few towns or states have any kind of systematic records of where culverts are located, their condition, or their past failures.

Communities need an easily-accessible inventory and database of stream crossing infrastructures to which they can add their own specific knowledge, and also collect information about vulnerable culverts and crossings. This can help them prioritize further assessments, applications for mitigation grants, or expenditures of limited funds; and it can help them work with neighboring towns and cities to reduce hazards throughout a river system. An added benefit is that the data that would be required and documented for each stream crossing could provide much of the needed material for permit applications for crossing upgrades, expediting the upgrade permitting process (see Example 8: Stream Crossing Inventories and Databases, p. 47).

Municipal Need #2 Element e) Financial help to plan and construct needed upgrades

Finally, municipalities need upgrades to be affordable. Larger culverts and crossing structures are more expensive in the short run. The permit and design process adds to the cost.

Highway moneys and local budgets are the sources of funding for most culverts. But these are limited, especially for small towns. FEMA's Hazard

Example 8. Stream Crossing Inventories and Databases

An inventory of stream crossings is a way for people to record data systematically on the status of stream crossing infrastructure. A wide variety of data can go into an inventory, and a range of people may be able to enter that data.

Examples of data that could go into a stream crossing inventory, and who might put it in:

- Local public works officials record when a crossing structure was put in, its size, and maintenance dates

- River scientists record the physical measures of a stream that indicate risk of erosion or stream channel movement.

- Transportation planners input information on how many vehicles travel over the stream crossing each day, and its importance to local and regional transportation networks.

- Ecological scientists input data on habitat quality, protected fish and wildlife species, etc.

It is important that methods for acquiring and inputting data be standardized.

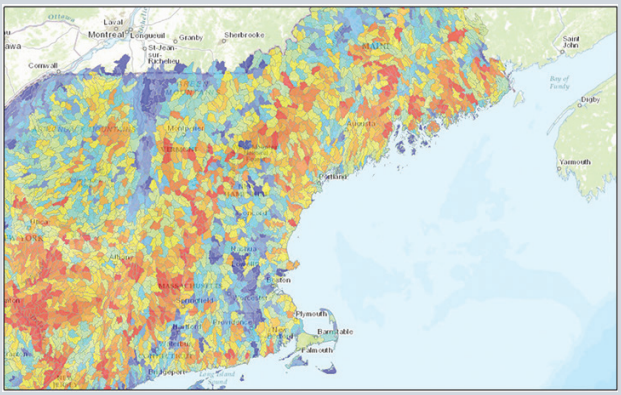
Once an inventory is done on many stream crossings, it can be put into a database, and this database can be made accessible via the web.

Stream crossing databases help town officials, as well as agency regulators and funders, to make informed decisions about site-specific needs. They can also help them decide which stream crossings are priorities for upgrades. A database can also be linked to geographic tools to allow visual summaries of entire stream networks and regions. Computer models can calculate whether upgrading a stream crossing in one location might have beneficial or harmful effects on other crossings, or whether upgrading two in a row at one time is necessary to reap the benefits.

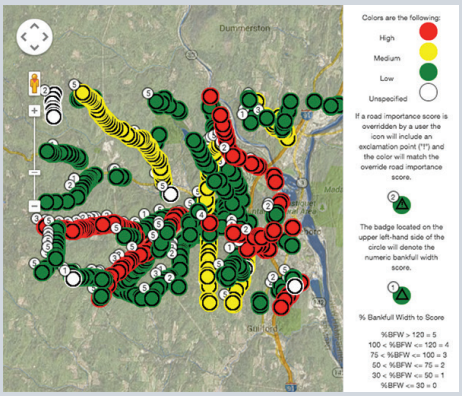
The North Atlantic Aquatic Connectivity Collaborative's database is a longstanding stream crossing database (formerly called the Stream Continuity Database) in the US Northeast. Up until now, it has focused on improving stream connectivity for aquatic species. The collective has developed common protocols and trainings for assessing road-stream crossings and a regional database for this information. Using these tools, crossings can be examined and prioritized for improvements within and across watersheds and borders. Currently UMass and the Massachusetts Department of Transportation are working to augment this database with assessments that examine

1) Geomorphic condition; 2) Ecological condition, including connectivity; 3) Condition of culvert or other structure; 4) Hydraulic capacity; 5) Importance of road to emergency response routes

Another stream crossing database already working in New England is vtculverts.org. VTrans, the Vermont Agency of Transportation, maintains vtculverts.org as an inventory of all river and stream crossings in the state. It is linked to the state natural resources atlas (see Example 3), which has data on geomorphic conditions as well as aquatic organism passage. Among other things, this allows local officials to come up with capital budgeting plans that prioritize crossing replacements based on condition and risk of failure.



NAACC's online database, showing subwatersheds in New England and beyond that may be higher priority for field survey. The prioritization criteria included fish population data, likelihood of crossing failure, and impact of crossing failure. Available at: https://www.streamcontinuity.org/assessing_crossing_structures/prioritizing_crossings.htm



Vtculvert.org's database, here indicating the importance of the roads crossed by culverts in the Town of Brattleboro. Red means high importance, yellow medium, and green low. Small numbers in white circles are a rating to indicate the size of the culvert relative to the river's bankfull width. A low bankfull number for a culvert that crosses a road of high importance may indicate a priority culvert for upgrading.

Mitigation grants can pay for bigger projects but moneys for these grants are even more limited, and available only after a declared emergency. Also, small towns often find it too cumbersome even to apply for FEMA grants, as they require baseline studies and designs that are costly for a small community. Moreover, FEMA and other funding agencies often pay only 75 percent of a culvert replacement – and that is often only for an in-kind replacement. The up-front expense of 25 percent of the cost for a crossing, or considerably more for an upgraded crossing, can be prohibitive for small towns. Very simply, New England's communities need better, easier, and more reliable funding support to pay for stream crossing upgrades for vulnerable and damaged crossings.

Sometimes, of course, towns and cities will have to pay the cost themselves. This can be cost-effective for municipalities in the long run, as there will be reductions in maintenance and repair. However, the needed 30-to-50-year budgeting is beyond the capacity of many small towns. Communities would benefit from assistance that could help them pay off the cost over time.

Recommendation #2: Support upgrades of vulnerable stream crossings across the six New England states

Building from our insights above concerning municipal needs related to upgrading vulnerable stream crossings, we identify five elements to support this recommendation.

Recommendation #2 Element a) Improve stream crossing regulatory standards to support upgrades, be consistent across agencies, and allow site-specific flexibility (well under way in New England)

All six states, in concert with the Army Corps of Engineers New England District, should continue to refine their stream crossing regulations, guidelines, and implementation. Some of the states are further along than others (see Example 9: Updating River and Stream Crossing Standards in New England, p. 49).

Stream crossing regulations should require structures that can accommodate high to extreme flows of water, sediment and debris. Where damage from river floods is likely, stream crossing infrastructure should be wider than the normal stream, tall enough to accommodate high flows and large debris, and should pass water, sediment, debris and aquatic organisms as a normal, continuous part of the stream. Regulations should call for the shape and surface of the stream bottom to simulate natural stream shape, slope, and dynamics, matching that upstream and downstream. Open-bottomed stream crossings should be strongly encouraged.

Additionally, standards need to be made consistent and enforceable across a state's agencies, along with the Army Corps General Permit (see Example 7: State Stream Crossing Standards Meet Federal Funding Requirements, p. 46).

At the same time, state agencies, the Army Corps of Engineers, and FEMA should continue to discuss how stream crossing regulations can specify requirements for different site-specific conditions. A key may be to prioritize performance standards rather than design standards – performance standards that include not only the ability to pass water, but also the ability to pass sediment and debris, and to maintain and restore natural levels of sediment movement. In New England, only Vermont and New Hampshire presently have sediment-based performance standards of this sort, and federal agencies have yet to adopt any. New Hampshire's stream crossing performance standards require, for example, that crossings "not be a barrier to sediment transport" and "not cause erosion, aggradation, or scouring upstream or downstream of the crossing."

Within this consistent but flexible system, all agencies should prioritize support for upgrades of crossing infrastructure at the most vulnerable crossings. These can be identified and rated with a stream crossing inventory and database (see D, p. 50).

Recommendation #2 Element b) Streamline permit and funding processes and requirements, and incentivize replacing vulnerable and damaged crossings with upgrades

Regulatory agencies should change the incentive structure so that municipalities are encouraged to

upgrade vulnerable and damaged crossings rather than construct in-kind replacements. This means:

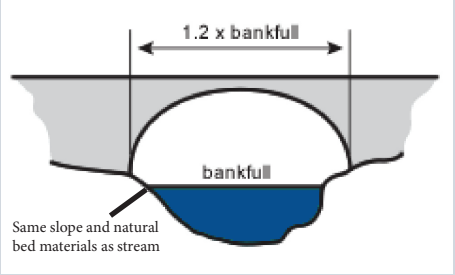
- Allow towns and cities to upgrade damaged structures during emergencies, with little to minimal permitting delay
- Fund the same proportion of the cost for upgrades of vulnerable and damaged crossings as for in-kind replacements
- Require cost-benefit analyses of designs to look at 30-year or 50-year costs, including replacement and repair, and develop systems to account for off-site benefits, including flood damage reduction downstream, and benefits to the environment, recreation, and the community economy.

All of these measures would be aided with a stream crossing database that provided a set of design templates (see C, below) and objective prioritization of crossings that need upgrades (see D, below). Crossings above a certain prioritization should be approved and funded for upgrades, provided the upgrades are constructed with appropriate designs. During emergencies, this should be done with little additional analysis or permitting paperwork required.

Recommendation #2 Element c) Develop and make available easy-to-follow design templates and guidelines for upgraded crossings, which will receive expedited permitting and funding review with high likelihood of approval

Federal and state agencies should develop, or support the development of, template designs for upgraded stream crossings. One approach would be for state or federal agencies to develop a set of design templates

Example 9. Updating River and Stream Crossing Standards in New England: Stream Continuity and Structural Resilience



Some typical requirements in recently upgraded stream crossing standards in New England.

New England is ahead of many other regions of the country in updating its stream crossing standards, thanks to wide collaboration and learning among universities, non-profit groups, and federal and state agencies.

One key impetus was the development of a set of model standards in the early 2000s by the River and Stream Continuity Partnership, a collaborative among UMass Amherst, state and federal agencies, Massachusetts' Riverways Program, and The Nature Conservancy.

These standards initially sought to achieve three main goals: 1) Fish and aquatic organism passage; 2) River/stream continuity; and 3) Wildlife passage. The standards included both metrics and performance standards – for example, they recommend crossings be at least 1.2 times the bankfull width of the stream, and they should have the same slope and natural bottom substrate as the stream directly upstream and downstream.

In 2005 these standards were included in the U.S. Army Corps of Engineers General Permit for Massachusetts. Since then, agencies across the region have adopted portions of the standards. For example, the Massachusetts Department of Environmental Protection borrowed from the standards in its 2014 update of the state's Wetlands Protection Act. MassDOT (the Massachusetts Department of Transportation) refers to these standards in its handbook. In the most recent revisions of the Army Corps General Permit for each of the six states, the Army Corps and The Nature Conservancy worked with state agencies and stakeholders in each of the six New England states to incorporate aspects of the stream continuity standards in all six General Permits.

Though initially written to help fish and wildlife, crossings built to stream continuity standards have also proven to be more structurally resilient, thus improving public safety, while lowering long-term costs. When Tropical Storm Irene hit Vermont, crossings that had recently been built to new stream crossing standards informed by the River and Stream Continuity standards survived the storm while other crossings failed. Improved stream crossing standards thus saved valuable infrastructure, property, and, quite possibly, lives.

and guidelines for upgraded crossings, linked to particular sets of conditions. If towns demonstrated the conditions and used the template designs, they would be guaranteed more rapid review and a greater chance of approval and funding.

An alternative would be for state and/or federal agencies to pre-design upgraded crossing structures for the most vulnerable crossings. Then, towns and cities with crossings in this most vulnerable set would not have to do the cumbersome and time-consuming design work, agencies would not have to take the time to re-examine conditions and designs, and towns could move straight to construction. This approach would depend on a well-developed inventory, database, and prioritization system for vulnerable stream crossings, as described in D, below.

Recommendation #2 Element d) Develop and support an accessible inventory and database of stream crossings that identify vulnerable crossings

State and federal agencies should develop or adopt a widely available, user-friendly inventory and database of stream crossings that includes:

1. The physical condition of crossings
2. Their risk of fluvial hazard
3. Their importance to ecological connectivity
4. The significance of the transportation corridor they cross to emergency networks

Data should be able to be input by a wide range of people, including knowledgeable municipal leaders and staff. Training should be available to make sure that community members know why they should input data, and how to input data.

Based on this inventory, the database should be able to identify which crossings are most vulnerable to flood damage. It should also include an analysis of the effect of culvert upgrades on the vulnerability or resilience of upstream and downstream crossings. Based on these analyses, the database should then be able to prioritize which crossings are most vulnerable to flood damage, and which ones, if upgraded, would provide the greatest benefit to reducing flood damage. This should include prioritization and analysis of ways that upgrading some culverts may affect the vulnerability or resilience of others (see Example 8: Stream Crossing Inventories and Databases, p. 47).

This will require investment in building or adapting the database and a web-based platform; continual refinement of specific data that should go into the database; trainings on data collection and use; and ongoing resources to maintain and provide support for the database and its users.

Recommendation #2 Element e) Increase and diversify funding for stream crossing upgrades

States and federal agencies need to recognize that investment into upgrading stream crossing infrastructure will save money in the long run. To make it possible, however, there needs to be greater investment up front. Of course, it is important to use taxpayer-provided government funds as judiciously as possible. Increasing funding for stream crossing upgrades should include mechanisms that have limited over-all effect on state and federal budgets. Some creative mechanisms to help towns undertake needed upgrades include:

- Create or expand state revolving loan funds from which towns could borrow money to pay for culvert upgrades, then pay back the loan over an extended time (e.g. 30 years)
- A portion of highway moneys could be exclusively dedicated to stream crossing upgrades and available to communities
- State-level inter-agency groups could facilitate pooling of moneys to help pay for upgrades that fulfill multiple purposes
- Target state and/or federal appropriations to upgrade the highest priority crossings (based on database criteria), e.g. extra moneys to upgrade the top 5% priority crossings. These are the most likely to save money over the long term by avoiding likely repeat replacements.

Summary of Target Recommendation #3:

Support River-Smart Planning and Mitigation

Municipal need:
Prepare for and mitigate flood hazards through planning and land use
(See page 54).

Recommendation:
Support municipal efforts to prepare for and mitigate river flood hazards through planning and land use
(See page 55).

Municipal need elements:	Recommendation elements:
a) Assistance in preparing plans to address local and watershed-wide river flood hazard risks	a) Support municipal, multi-municipality, regional and state hazard planning that addresses river flood hazards
b) A diverse menu of mechanisms to achieve river-smart conservation, mitigation, and development; technical, financial and legal support.	b) Enable and promote a diverse menu of mechanisms for communities to achieve river-smart conservation, mitigation, and development; support with technical, financial and legal assistance.
c) Ongoing support until plans are implemented.	c) Ensure that support is available to communities on an ongoing basis, until their plans are fully implemented.

In this image from Floodready Vermont, the river has room to meander and flood its floodplain without threatening major infrastructure or property.

Target Recommendation #3: Support River-Smart Planning and Mitigation

Background

Besides helping streams and rivers flow better through culverts and other crossing infrastructure (Recommendation 2), there are three additional tangible actions that New England towns and cities need to take to become more resilient to river floods. These are: first, make sure rivers have room to move by ensuring their access to floodplains and river meander corridors; second, keep homes, property, and infrastructure as much as possible out of the way of rivers, and protect and mitigate where this is not possible; and third, direct development out of these areas to other, more river-smart locations. Thus, becoming river-smart requires several key land use management practices, each tailored for different areas of risk, opportunity, and development (see figure, next page).

- In areas at risk of river flood damage, development should be prevented and existing buildings and structures should be removed when and where possible ("protected areas" in diagram). In situations in which structures cannot be moved out of harm's way, buildings, infrastructure and land practices should be designed or redesigned to be resilient to river floods while minimizing the redirection of damage elsewhere ("vulnerable areas" in diagram).
- In undeveloped or less developed areas near streams and rivers, floodplains, river meander corridors, and riparian buffers should be conserved and restored ("river corridors" in diagram).
- In areas at minimal risk of river flood hazards, new river-smart developments should be constructed out of harm's way – outside of river meander corridors and floodplains ("safer areas" in diagram).

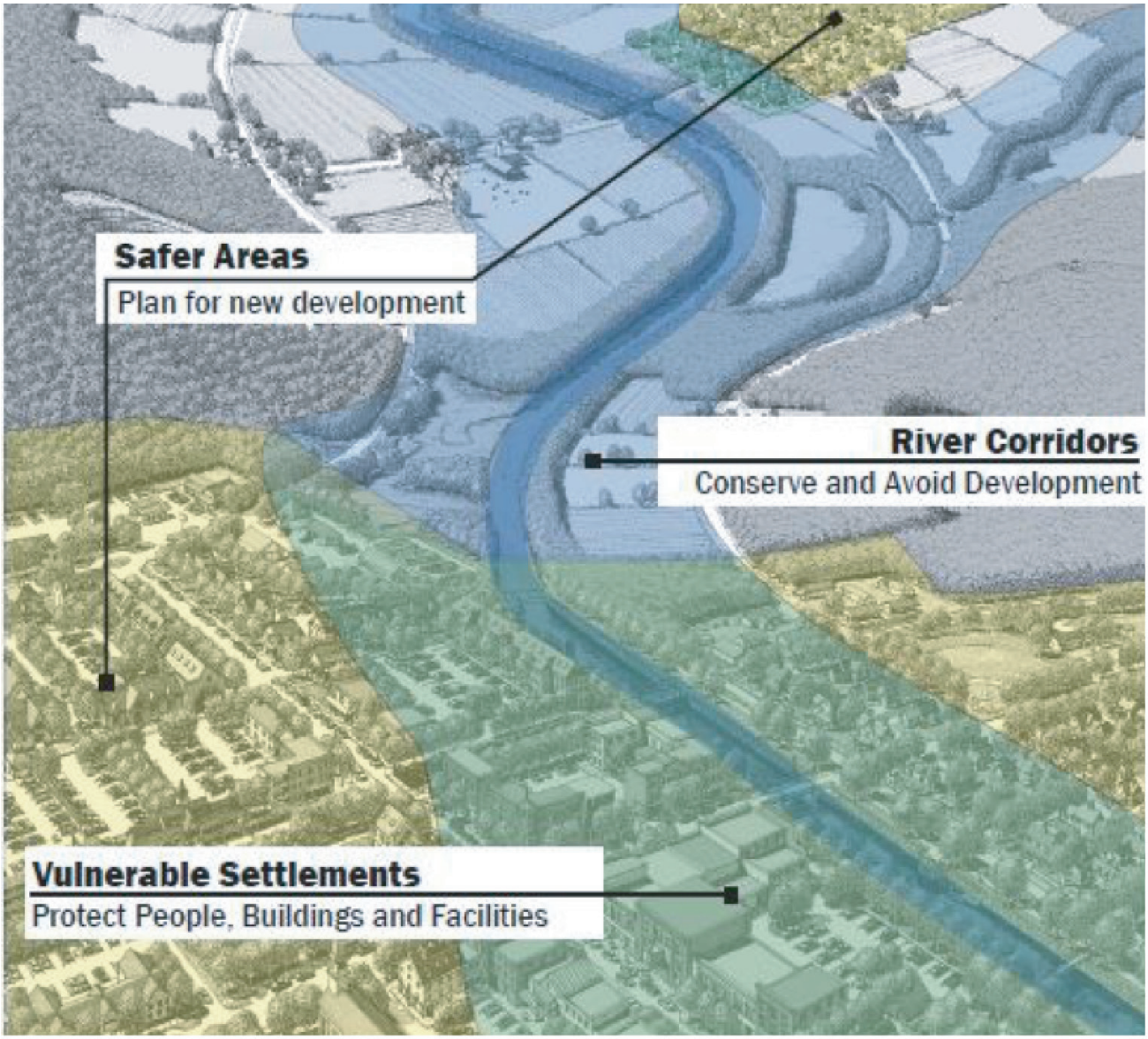
Towns need to coordinate these efforts with upstream and downstream neighbors so municipal leaders recognize and enact practices that will reduce vulnerability to flood damage for other towns and cities in their watershed.

Though these practices are crucial, New England communities face numerous challenges in putting them into action, and thus have significant need for assistance.

Among the challenges are:

- Municipalities may lack data and scientific analyses to know where and how to protect lands and waterways in their jurisdictions.
- The time and expertise needed for land use planning, mitigation and management are beyond the capacity of many small New England towns.
- Changing land use permanently is often expensive, requiring purchases, buyouts, easements, legal analyses and contracts, while reducing the municipal tax base.
- Proposals to regulate land use or purchase conservation lands are often contentious, and may require significant landowner negotiations and citizen outreach.
- There are few systems in place to facilitate and negotiate multi-municipal collaboration within watersheds, though mitigation in an upstream community can frequently reduce future flood damage in a downstream community.
- Actual work to implement new management on the ground is often expensive and requires technical expertise.

In short, changing land use to become river-smart requires numerous complex, multi-faceted tasks. New England's municipalities, especially the small towns in New England's more mountainous regions, cannot do these tasks without data, guidance, technical support, and financial help. The good news is that this is a sound investment for state and federal taxpayers because the land practices implemented in individual towns and cities can have watershed-wide and long-term benefits, ultimately saving many public and private dollars by reducing damage in river floods.



This diagram from the Vermont Rivers program illustrates the three on-the-ground actions besides culvert upgrades that New England towns and cities need to take to become more resilient to river floods (see Background, p. 52). 1) Make sure rivers have room to move by ensuring their access to floodplains and river meander corridors ("river corridors" in this diagram); 2) Keep homes, property, and infrastructure as much as possible out of the way of rivers ("river corridors" in this diagram) - and protect and mitigate where this is not possible ("protected areas" here); and 3) Direct development out of these areas to other, more river-smart locations ("safer areas" in this diagram).

Municipal need #3: Prepare for and mitigate flood hazards through planning and land use

Municipal Need #3 Element A) Assistance in preparing plans to address local and watershed-wide river flood hazard risks

The first step in adjusting land use in the ways listed above is for communities to plan. They need to gather scientific data, weigh costs and benefits, talk with residents about priorities and options, negotiate agreements, and coordinate with upstream and downstream neighboring towns and cities.

Key questions community leaders need to think about in order to reduce river flood hazards:

For areas at risk of river flood damage:

- What areas, properties and structures are at risk of river flood damage?
- Are there opportunities to move buildings and infrastructure out of harm's way?
- For buildings and infrastructure that cannot be moved out of harm's way, how can hazards be mitigated so these become more resilient to river floods?
- Are buildings, infrastructure, or flood control structures diverting hazards elsewhere? If so, how can these secondary effects be mitigated?

For undeveloped or less developed areas in and near streams and rivers:

- In which areas would allowing rivers room to move lessen river flood power and volume?
- Where may there be opportunities to protect or restore floodplains, river meander corridors, or riparian buffers?

For areas at minimal risk of river flood hazards:

- What areas are safe from river flood hazards and desirable for development?
- How can development be promoted in these river-smart locations?

To coordinate with other municipalities:

- Are there opportunities for conservation or mitigation by coordinating with upstream or downstream towns?

To find mechanisms:

- What mechanisms can and should be used to achieve these goals, and what strategy for action best fits local and regional culture, values, and capacities?

If communities are to take the lead in planning for river flood hazards, they can most readily do this by incorporating fluvial hazards into multi-hazard mitigation plans. Hazard Mitigation Plans are one of the most important tools used by regional and municipal planners to increase long-term flood resiliency. They are guided by FEMA, and enable towns and cities to qualify for a range of grants and insurance opportunities. However, the existing focus under flood hazard planning is inundation hazards (see Example 2, Inundation Versus Fluvial Hazards, p. 16). New England towns need fluvial hazards to be included within long-term, multi-hazard planning.

Hazard mitigation planning requires large upfront costs, time, and technical skill – for pre-studies, hazard assessments, legal analyses, facilitated community conversations, project designs, and other tasks. Few New England municipalities have the in-house expertise or staff to do all this, so they must hire consultants, while investing limited staff time to monitor the work and facilitate decision making. Towns and cities, especially small towns, need financial help and close technical guidance to make river flood hazard planning possible.

Additionally, in order to effectively mitigate river flood hazards, communities need systems of planning that can work across many towns. Unfortunately, there is no good mechanism or structure for watershed-wide planning for river flood hazards for most of New England's municipalities. FEMA's hazard mitigation planning requires local governments to individually adopt plans. Towns and cities need either facilitated coordination with other municipalities in their watershed, or else they need larger-area entities – substate regions or states – to take the lead on planning for river flood hazards.

Municipal Need #3 Element B) A diverse menu of mechanisms to achieve river-smart conservation, mitigation, and development; technical, financial and legal support.

If towns and cities are to conserve and restore river floodplains and river meander corridors, promote river-smart development, and mitigate where investments cannot be moved out of areas at risk, they need to have a range of legal and administrative mechanisms to achieve these management objectives.

Towns and cities have several specific needs related to legal and administrative mechanisms:

- A robust, accessible, comprehensible menu of options
- In-depth, user-friendly technical support and legal guidance to consider and move forward with specific options
- Legal backing for land use regulations: counsel to defend chosen river-smart zoning rules and ordinances against legal challenges, and supportive state and federal laws and rules to promote or require river-smart conservation, development and mitigation.

Municipal Need #3 Element C) Ongoing support until plans are implemented.

With careful planning and preparation of options, towns and cities can move forward on changing land use management to improve river flood resilience. Unfortunately, too often federal and state agencies provide support through the preparation stages, but then town officials and staff are left largely on their own to implement the land use change. Communities need continued technical, financial and legal support and guidance.

Recommendation #3 Support municipal efforts to prepare for and mitigate river flood hazards through planning and land use

Federal and state agencies, legislatures and programs must support community fluvial hazard planning and mitigation. Federal movement on this is crucial, as FEMA and other federal agencies are central sources of guidance and grant programs for hazard planning mitigation. However, if federal agencies are slow in including fluvial hazards, states should lead the way, as Vermont has done. It is no coincidence that almost all the Examples under this recommendation come out of Vermont, for it is far in the lead in New England.

Recommendation #3 Element a) Support municipal, multi-municipality, regional and state hazard planning that addresses river flood hazards

In order for New England towns and cities to be able to withstand and mitigate river flood hazards, federal and state agencies need to help them plan. Several measures are needed for this.

- Standardized, statewide (or nationwide) fluvial hazard assessments (see Recommendation 1).
- Federal and state agencies should recognize fluvial hazards as a primary hazard for communities, and guide towns and cities to analyze fluvial hazards in their multi-hazard mitigation planning. Vermont has taken the lead for this in New England (see Example 10: Vermont Support for Municipal Flood Hazard Planning, p. 56).
- Federal and state programs should provide reliable funding and support to towns to complete the Hazard Mitigation Plan process. One kind of limited but significant financial assistance is an incentive program in which communities become eligible for other funds if they plan (see Example 12: Vermont's Emergency Relief and Assistance Fund, p. 57). Technical support may best be provided by substate regional agencies or organizations that know federal and state policies and also the particular needs of individual towns and cities, and can act as cost-effective intermediaries. Federal and state governments could provide incentives and funding directly to these intermediaries to work with towns to develop more complete and effective plans (see Recommendation 5).

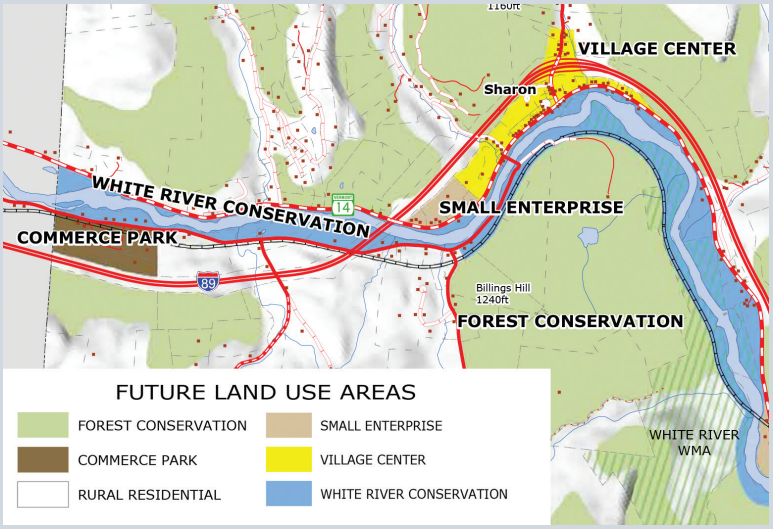
Example 10. Vermont Support for Municipal Flood Hazard Planning

In Vermont, all municipal plans written since July 2014 must consider fluvial hazards (24 VSA Chapter 117 §4382). Specifically, new municipal plans must include a flood resilience plan that:

- "identifies flood hazard and fluvial erosion hazard areas… and designates those areas to be protected, including floodplains, river corridors, land adjacent to streams, wetlands, and upland forests, to reduce the risk of flood damage to infrastructure and improved property"
- "recommends policies and strategies to protect the areas identified… and to mitigate risks to public safety, critical infrastructure, historic structures, and municipal investments."

How do these new municipal plans interact with multi-hazard mitigation plans? Vermont's municipal and flood resilience plans are not explicitly part of a town's Local Hazard Mitigation Plans, which are usually prepared under guidance from FEMA. However, a municipal plan may reference a local hazard mitigation plan. It is anticipated that as communities begin to integrate hazard mitigation planning into municipal plans, and fluvial hazard plans into hazard mitigation plans, the two plans will become more integrated and effective. Vermont provides incentives for municipalities that have undertaken flood hazard planning (see Example 12, Vermont's Emergency Relief and Assistance Fund, p.57).

http://floodready.vermont.gov/update_plans/municipal_plan



Planned future land uses in Sharon, VT Town Plan, Adopted April 6, 2015.

- States and substate regional agencies and organizations need to facilitate the development of multi-town hazard mitigation plans that address river interactions throughout watersheds – or they should undertake this planning themselves. Federal agencies should support watershed-scale planning by supporting towns and cities that participate in multi-municipality plans, or in state or regional plans, with access to special grants and/or insurance discounts.

Example 11. Flood Ready Vermont

Vermont has developed a comprehensive website with an array of information to help municipalities and others become more river-smart. The website includes information on community risk assessment and reports, a Vermont Flood Ready Atlas, information on River Corridors, instructions on plan updates, community efforts, sample plans, and much more to help municipalities plan and prepare in a flood resilient manner. This is designed to be particularly user-friendly, supplementing the state's resource-rich Vermont Rivers Program websites.

Recommendation #3 Element B) Enable and promote a diverse menu of mechanisms for communities to achieve river-smart conservation, mitigation, and development; support with technical, financial and legal assistance.

Federal and state agencies should collaborate to develop comprehensive systems that can provide towns and cities with a range of mechanisms to achieve river-smart conservation, mitigation and development.

Mechanisms to achieve river-smart development might include any of the following, for example:

- State or federal regulations or zoning rules
- Local zoning rules, bylaws and ordinances
- Incentives for landowners or developers, and voluntary agreements with landowners
- Land purchases, buy outs, and easements
- Negotiated agreements with other municipalities
- Targeted economic and community development programs for river-smart development.

Systems of support for these mechanisms should include the following:

- A centralized, easily accessible source of user-friendly information on a range of options and mechanisms to achieve river-smart land use. Web sources such as floodready.vermont.gov are good places to do this (see Example 11: Flood Ready Vermont, p. 56).
- Technical and legal assistance that is coordinated across relevant agencies, to help town and city leaders and staff to choose, prepare and implement river-smart options. Funds for on-the-ground assistance may be best spent by underwriting staff in substate Regional Intermediary organizations (see Recommendation 5).
- Models of bylaws, zoning ordinances, land purchases, buy-out opportunities, easements, voluntary agreements, economic development programs and other legal and administrative mechanisms that may be used to achieve river-smart land use.
- Financial assistance. There are many creative ways to provide this, including loan funds and financial incentives for river-smart planning and mitigation (see Example 12: Vermont's Emergency Relief and Assistance Fund. p. 57).

Example 12. Vermont's Emergency Relief and Assistance Fund

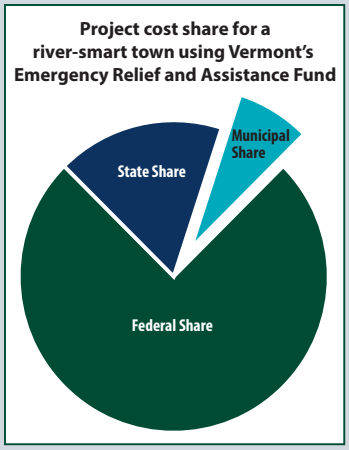
One innovative policy approach to finance and encourage river-smart planning and mitigation is to give additional financial support for flood recovery to towns that plan and prepare for fluvial erosion hazards. Vermont's Emergency Relief and Assistance Fund provides 30% to 70% of the non-federal match required (7.5% to 17.5% of the total project cost) for communities that receive federal disaster relief from FEMA Public Assistance. A greater portion is paid if municipalities engage in river- smart planning and adopt river-smart bylaws.

Municipalities can receive the maximum portion, with 70% of their non-federal match paid by the state, if they:

- Adopt new river-smart state Town Road and Bridge standards
- Adopt or take steps toward adopting flood hazard bylaws
- Adopt a Hazard Mitigation Plan and an Emergency Operation Plan
- Adopt a river corridor protection bylaw that meets or exceeds state model guidelines

The municipality then covers only 7.5% of the total project cost.

Funds are provided from the state's General Fund Budget Stabilization Reserve, which can be used for emergency relief and assistance. Up to 2% of this state reserve fund can be transferred to the Emergency Relief and Assistance Fund in a given fiscal year.



Municipalities in Vermont that have moved toward more river-smart planning and standards can receive state financial assistance that makes river-smart projects much more affordable.

http://floodready.vermont.gov/find_funding/emergency_relief_assistance

- Legal counsel and backing to defend new river-smart zoning and other ordinances. Straightforward legal analyses of past cases, written in non-expert language, may be helpful.
- National and statewide regulations and/or programs for river-smart conservation, development and mitigation. These can provide structure and backing for localities to follow, and can more readily achieve coordination of conservation and mitigation practices up and down river systems. An excellent example of a state-based program that advances conservation and mitigation for river flood safety is the Vermont River Corridor program (see Example 13: Vermont River Corridor Program, p. 58).

Recommendation #3 Element C) Ensure that support is available to communities on an ongoing basis, until their plans are fully implemented.

State and federal agencies should provide close guidance and support for towns all the way until implementation of river-smart measures is complete (see Example 20: Local Support and Partnerships from Concept to Completion, p. 72). Though financial support should come from federal and state budgets, it may be most cost-effective and sensitive to individual state and town culture and needs if it is led by substate regional organizations (Recommendation 5).

Support should include:

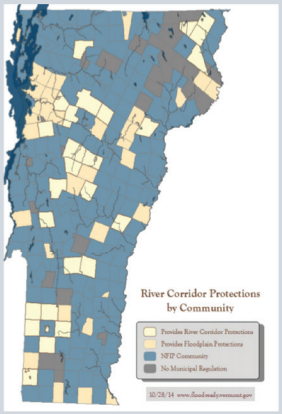
- Consultation and advice as new issues and details arise during the implementation support
- Financial support as towns and cities undertake the significant expenditures of removing levees and berms, purchasing easements, and protecting infrastructure from risk of fluvial hazards
- Legal counsel, whether to ensure correct management on easement lands or lands with voluntary agreements, or to defend new river-smart zoning regulations against legal challenges.

Example 13. Vermont River Corridor Program

The Vermont River Corridor and Floodplain Program, established in 2011, aims to protect lands in order to allow rivers to move in ways that help maintain a stable and minimally erosive river. The river corridor contains the meander belt and a riparian buffer. Depending on the sensitivity of the river or stream, the meander belt width ranges from the existing channel width to 8 channel widths. The riparian buffer is a 50 foot setback on either side of the meander belt. The riparian buffer provides additional room for stable meanders, bank stabilization, and establishment of woody buffer that can resist lateral (sideways) erosion. River meander corridors are designed to ensure compliance with state law and the Vermont Flood Hazard Area and River Corridor Rules.

Vermont's Department of Environmental Conservation carries out the river corridor program while working with municipalities, Regional Planning Commissions, and state agencies. The first step is to map river corridor areas throughout the state. Then, the Department of Environmental Conservation provides technical assistance and works with partner agencies to complete river corridor plans and stormwater master plans. Municipalities can get help to implement site-specific best management practices, which can include avoiding and removing encroachments; slowing, spreading, and infiltrating runoff; and river and riparian management. In addition, the state provides model bylaws and incentives to assist and help municipalities in adopting river corridor protection bylaws and ordinances. The State Program also offers to review projects for compliance with local erosion hazard provisions if a municipality needs that type of technical assistance built into the bylaw.

http://floodready.vermont.gov/food_protection/river_corridors_floodplains/river_corridors



A river corridor in Vermont. The red lines mark the meander belt, and the yellow lines the 50 foot riparian buffer. On left, yellow marks municipalities that have adopted river corridor protection areas.

Summary of Target Recommendation #4:

Provide Outreach and Training on River Dynamics and River-Smart Practice

Municipal need:

Information and training on river dynamics, lessons for river flood hazards, and river-smart hazard mitigation.

(See page 60).

Recommendation:

Prepare and disseminate outreach materials and training on river dynamics, lessons for river flood hazards, and river-smart best management practices.

(See page 61).

Municipal need elements:	Recommendation elements:
a) Engineers and work crews that build and maintain roads and bridges need to understand river dynamics and implement best management practices	a) Train transportation work crew personnel in New England on river dynamics and river-smart best management practices
b) General information on river dynamics and practical lessons for land managers	b) Produce easily understandable outreach materials on river dynamics and practical lessons for land management; disseminate widely, especially to land use decision makers
c) Occasional, episodic access to in-depth information and targeted trainings, on river science and best management practices	c) Prepare in-depth outreach materials; create, publicize and maintain systems to deliver these quickly and efficiently upon request

Target Recommendation #4: Provide Outreach and Training on River Dynamics and River-Smart Practice

Background

People in streamside New England communities are often shocked by the scale of damage they experience during river floods. After Irene, a common theme in media reports was people's horrified surprise that tiny brooks and familiar rivers could become torrents that could collapse bridges, houses and highways. This is not uncommon – people in many places and times have been shocked by the damage flooding rivers can do. We imagine hurricanes and tornadoes as destructive, but not the rivers we think we know so well. Nonetheless, around the world, damage from river floods exceeds that from hurricanes and tornadoes.

It would benefit the residents of New England to gain a deeper understanding of rivers as dynamic systems that flood, move, and sometimes suddenly change their landscapes. If New Englanders had this understanding, they would likely be better prepared for these events in advance. An understanding of river science could inform good decision-making as towns and cities rebuild after river floods, and as they plan and prepare for future river floods. Besides scientific knowledge, information about best management practices to accommodate natural, dynamic river processes through land and river management would assist New England's communities to become more river-smart.

It is tempting to call on federal and state agencies to undertake a wide and deep education, information, and training campaign on these topics across the communities of New England. However, given their real constraints they must work strategically, and we must all work collaboratively. Though widespread general understanding is desirable, not all residents or officials of New England towns have the time, interest or capacity to devote themselves to these subjects. Towns may find it most effective to have a few key staff people more deeply trained, who can then become resources for others as the need arises. Information may not be equally needed at all times. When river floods are imminent or have just happened, information may be drastically needed. At other times, a host of other community needs may rise to top priority instead. Government agencies in New England need to develop, fund, and carry out education and training programs about river science and best management practices for people across the region's communities in ways that makes information available as communities need and want it most.

Three specific educational and training needs of municipalities rise to the top as most critical for long-term river flood safety and resilience. Addressing these will provide the largest "bang for the buck" for state and federal investment in education and training.

Municipal need #4: Information and training on river dynamics, lessons for river flood hazards, and river-smart hazard mitigation

Municipal Need #4 Element a) Engineers and work crews that build and maintain roads and bridges need to understand river dynamics and implement best management practices

There is one group of people who, when educated in river science and trained in best management practices, could immediately and tangibly improve the resilience and preparedness of New England communities in the face of river floods. These are the engineering and construction workers who build, maintain, and repair the roads, bridges, and other infrastructure on which New England's towns and cities depend. They include staff from local departments of public works, state Department of Transportation crews, federal transportation workers, and transportation contractors. These crews are often first on the scene in a flood emergency, and every day they maintain towns' access to a host of resources and connections.

New England's municipalities need transportation engineering and construction workers to be able to construct, maintain and repair infrastructure in ways that will reduce, rather than increase, future river flood damage. They need these work crews to be able to do this fast, right away. For these reasons, towns need the people in their road crews to be educated in river dynamics, especially how rivers interact with built structures, and to be trained with a toolbox of best management practices.

Municipal Need #4 Element b) General information on river dynamics and practical lessons for land management

Most town and city residents do not need as much knowledge about river dynamics, or skills in best management practices, as transportation crews working in and around towns and cities. However, municipalities would be able to prepare and deal with river floods better if their officials and residents had some general knowledge about river science and practical lessons for land management, and if one or a few long-term staff had some deeper knowledge.

Two kinds of information are key. First, information is needed on the general dynamics and impacts of river floods – in other words, a general sense of how rivers act during floods, and some of the practical implications for property and infrastructure, such as the key insights covered in Chapter 2. Second, information is needed on how to predict, prepare for, and mitigate river flood damage. Most importantly, community leaders and residents should know they can reduce their own vulnerability to damage, and others' vulnerability downstream and elsewhere, by managing lands in ways that allow flooded rivers to dissipate their force and volume.

Towns' land use decisionmakers are in particular need of this general information. These include planning commissioners, zoning board members, and conservation commissioners. Landowners of streamside areas, tenant-occupants of those areas, and other municipal officials, staff and decision makers of various kinds also need to be recognized as land use decision makers. Finally, towns may also find it easiest to designate one or a few staff members who become more deeply trained, and can become resources for others in the community.

Municipal Need #4 Element c) Town leaders, staff, and property owners need occasional, episodic access to in-depth information and targeted trainings, on river science and best management practices

There are times when officials, landowners, or residents of New England communities may suddenly need or want to gain deeper knowledge about river flood hazards or best management practices for mitigating river floods. These times might include during a flood emergency, when preparing for a construction project, or when a municipality engages in more in-depth planning for flood hazard mitigation.

There is no easy way to predict when this need will arise. Communities need information to be available and easy to access at all times. They need a number to call, and a website to search – and they must know where to find that number and website. On the other end of that call and website, they need useful information that can be dispatched efficiently, in forms that can support rapid, easy learning of new material. They also need staff from outreach organizations to be ready to act quickly to take advantage of a learning moment, and guide the range of construction and reconstruction activities that may follow a flood.

Recommendation #4: Prepare and disseminate outreach materials and training on river dynamics, lessons for river flood hazards, and river-smart best management practices

We recommend that federal and state agencies prepare and distribute outreach materials and training on river dynamics, lessons for river flood hazards, and river-smart best practices. This should be done in targeted ways in order to be the most cost-effective. We identify three key elements to support this recommendation.

Recommendation #4 Element a) Train transportation work crew personnel in New England on river dynamics and river-smart best management practices

Educating and training New England's transportation personnel is worthy of significant targeted investment from state governments and federal agencies. This is because it can bring immediate improvements in public safety, and in the long run will significantly reduce costs to the taxpayer. All transportation personnel who work on the region's roads and bridges – federal, state, local, and private – should receive training on river science and river-smart best management practices, with more in-depth training given to engineers, foremen, and other crew leaders. Once established, transportation agencies should incorporate this as part of their ongoing education and training programs.

Education and training content should include:

- Background on river science. This should explain the ways in which roads, bridges and other structures influence, and are impacted by, river dynamics and floods
- Best management practices for construction and maintenance of bridges and roads that will reduce rather than increase future river flood damage

Delivery mechanisms should include:

- Hands-on field trainings and practice, especially on best management practices
- Classroom and/or web-based presentations on background information
- Web-based materials for self-guided education and practical training that can supplement more directed seminars and trainings

Programs could be modeled or built on the Vermont Rivers and Roads Program, developed since 2011's Tropical Storm Irene (see Example 14: Vermont Rivers and Roads Program, facing page). Building on an existing program would save other states and federal agencies time and costs of program development. Vermont has also developed on-line materials that might potentially be used by others, such as the Vermont River Management Principles and Practices, a technical guide on how communities can evaluate alternatives and design post-flood projects to recover quickly, while also advancing long-term resiliency.

Recommendation #4 Element b) Produce easily understandable general outreach materials on river dynamics and practical lessons for land management; disseminate widely, especially to land use decision makers

State and federal agencies should develop and make widely available outreach materials that cover general, practical lessons on river science and river-smart land management. The essential content should be background on river dynamics, with practical lessons for land management (such as the key insights emphasized in Chapter II); and guidance on how to manage lands in river-smart ways. Particularly important for this guidance is information on how lands can be managed in ways that will allow flooded rivers to dissipate their force and volume.

Possible products and outlets include fact sheets, web portals, pamphlets and posters, public media announcements, public and community television and radio programs, and information tables at events. It is essential that the information be clearly and engagingly presented, that it should seem both respectful and immediately useful to its targeted audience (see Example 15: Community-Friendly Outreach Materials, p. 64).

There should be targeted outreach to land use decision makers – land owners, occupants of rented lands, and a range of community officials and staff who make decisions related to land use, from issuing permits to passing ordinances to appropriating town funds for construction activities. The most cost-effective way to do this may be to enlist state, federal, regional and nonprofit agencies that already work with these groups to include these materials in their outreach activities.

Example 14. Vermont Rivers and Roads Program

After swollen rivers damaged hundreds of road sites in Vermont during Tropical Storm Irene, leaders of both the Vermont Rivers Program and the Vermont Agency of Transportation (VTrans) realized there was a problem. Roads needed to be built better, with river-smart construction, so they could have a greater likelihood of withstanding major floods. Yet immediately after Irene, in the rush to get things working again, many roads and bridges were reconstructed with the previous designs, ensuring repeated vulnerabilities into the future. This was because on-the-ground personnel did not always recognize the river dynamics at work, and there was neither the time nor the availability of staff from the Vermont Rivers Program to provide assistance at the hundreds of repair sites across the state.

The Vermont Rivers Program and the Vermont Agency of Transportation decided to develop a training program in which VTrans employees would be trained to understand, identify, and plan for river processes that might affect future structural resilience, and to request and provide needed assistance. The goals were for on-the-ground transportation crews to increase their capacity to rebuild river-smart structures themselves during less difficult situations, whether after a storm event or during normal maintenance operations; and to recognize challenges and request assistance in more difficult situations. It was hoped that VTrans design staff and others would also be better prepared to provide assistance on these more difficult sites.

The result was the Vermont Rivers and Roads program. The training includes information on fluvial geomorphology, hydrology, and aquatic habitats of rivers. Participants learn how instream construction interacts with these dynamic aspects of rivers. The training series includes multiple tiers:
Tier 1: Online introduction to river processes. This is publicly available to everyone.

Tier 2: A 3-day classroom and field-based training on accommodating river processes and aquatic habitat.

Tier 3: Advanced class and field training on the application of the Vermont Standard River Management Practices.

By February 2015, over 200 VTrans employees had already completed the intensive 3-day Tier 2 training, as had over 300 municipal, regional, and private-sector personnel.

http://wsmd.vt.gov/rivers/roadstraining/

VTrans Working to Get You There
Vermont Agency of Transportation
TRAINING CENTER

Recommendation #4 Element c) Prepare in-depth outreach materials; create, publicize and maintain systems to deliver these quickly and efficiently upon request

State and federal agencies need to have more in-depth information on river floods and river-smart hazard prevention readily available. This information should be easy to find and disseminate so that when town and city officials, residents, or landowners have a sudden need for it, they can find it quickly and simply.

In-depth written and interactive materials should be organized in clear, useful topics, such as: river dynamics; preparing and mitigating for river floods; best management practices for land management to reduce future river flood damage; funding sources for flood mitigation; regulations on building in flood hazard zones (see Example 16: StormSmart Communities, next page).

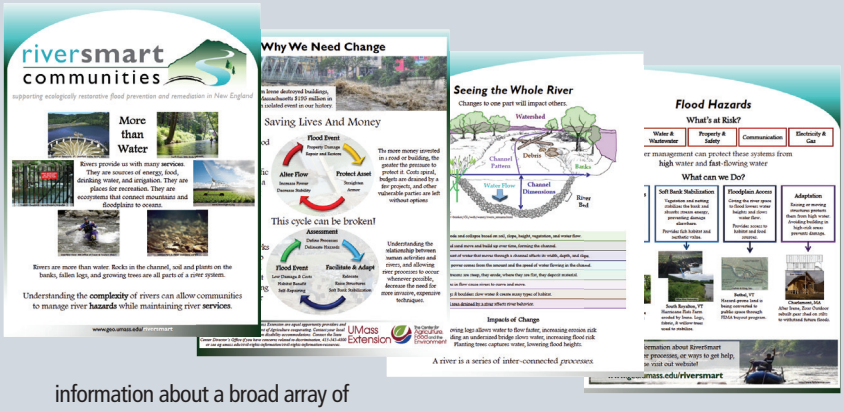
Because there may not be regional-scale river floods like those brought by Irene for another 20 or 30 or 50 years, public interest in this material may wane. When a flood does come, though, these educational materials should be immediately available, and immediately useful. To make this possible, federal and state governments need a system for updating this information, and for maintaining its accessibility and availability for years and decades to come. There are multiple ways to do this, but we suggest the following strategies:

- Identify one or two federal or state agencies that will be responsible for updating the information,

Example 15. Community-Friendly Outreach Materials: UMass RiverSmart Fact Sheets

Outreach materials need to be clear, informative, concise, and easy to access. UMass Amherst's RiverSmart Communities project is producing a series of informational pamphlets and packets with these goals in mind. These materials are geared to an audience of local government officials, community leaders, public works and highway staff, landowners, and the general public.

They are designed to help enable informed decision-making around river flood management, and to provide information about a broad array of river management topics. They are available in hard copy and also on the web.



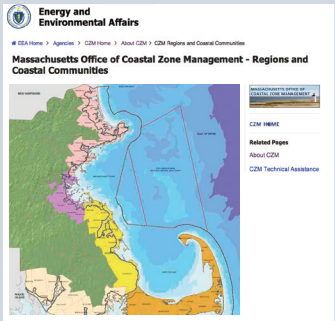
https://extension.umass.edu/riversmart

and for maintaining information offices and technical experts who can provide it upon request.

- Identify regional offices of these agencies, Regional Intermediaries (Recommendation 5), and/or central state offices and designate them as centers of these materials and related expertise. Hire and train one expert on river processes and flooding hazards for each of these offices, who can provide additional depth and expertise when requested beyond the prepared materials.
- Maintain informational materials, websites and expert personnel with funding that is reliable year after year.

Example 16. StormSmart Communities Program

An excellent example of a broad education effort to help communities prepare for future natural hazards is the Massachusetts StormSmart Communities program. Originally called StormSmart Coasts, the StormSmart Communities program was developed by the Massachusetts Office of Coastal Zone Management to help local officials prepare for and protect their communities from coastal storms and flooding —both now and in the future, when sea levels are expected to rise with ongoing climate change. The program aims to provide Massachusetts communities with tried-and-true actions and practical information that can be used to reduce risk. Whenever possible, the program taps into existing resources. Information resources are available in hard copy and on the StormSmart Communities web site. This program also provides ongoing assistance with local implementation of StormSmart strategies.
See: http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/stormsmart-communities/



From Coastal Zone Management website

Who to Contact and What to Do Before Building or Rebuilding

The coast, with its beach access and beautiful views, can be an attractive place to build a home or cottage—but it is important to be prepared for coastal storms and flooding. To protect public safety, coastal development, and natural resources, Massachusetts has enacted regulations that set minimum construction standards for coastal areas. These regulations cover various projects, including new buildings, repair of storm-damaged properties, additions, substantial improvement to existing or damaged buildings, septic systems, piers, and shoreline stabilization structures such as seawalls and revetments. In addition, building—or rebuilding after a storm—provides an excellent opportunity to maximize storm damage protection for your property. Through thoughtful planning and design, you can go beyond the minimum regulatory standards and use the best available techniques to minimize future property damage, significantly reduce your flood insurance rates, and preserve the capacity of natural landforms to buffer storm waves and flooding to further protect your property.

To help property owners with the permitting process, this fact sheet provides information on who to contact about applicable regulations, an overview of the most common permits needed, and recommendations for StormSmart building techniques to protect your property.

Excerpt from StormSmart Communities Factsheet

Summary of Target Recommendation #5:

Designate, Recognize and Support River-Smart Regional Intermediaries

Municipal need:
Integrated and ongoing assistance to become river-smart; improved delivery of related state and federal programs.
(See page 66).

Recommendation:
Designate, recognize and support river-smart Regional Intermediaries to provide low-cost and no-cost technical assistance to municipalities, and to guide and assist with federal and state programs.
(See page 70).

Municipal need elements:

a) Locally available agents who can provide integrated and ongoing assistance to help New England communities become river-smart.

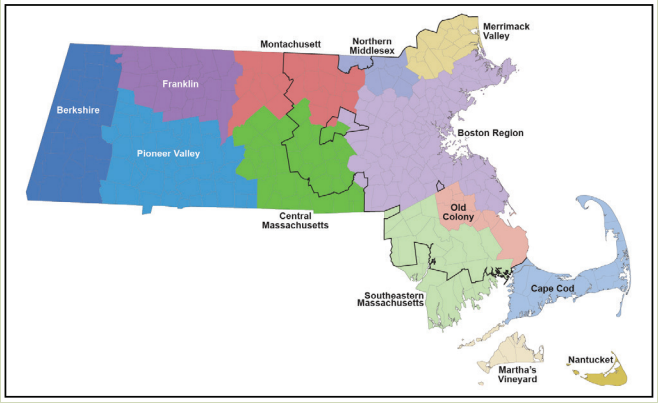
Recommendation elements:

a) Ensure that all municipalities in New England have access to a river-smart Regional Intermediary, whose mission includes low-cost service for municipalities and which has capable, reliable staff who respect towns' authorities and support towns' capacities.

b) Improved provision and delivery of state and federal programs and resources that aim to help New England communities become river-smart.

b) Use river-smart Regional Intermediaries to guide and assist with delivery of flood assessment, planning, mitigation and response services to local governments and landowners, and to gather and understand information on local needs and conditions.

All New England states have regional planning councils or agencies of some kind. This map shows Regional Planning Agencies in Massachusetts.



Target Recommendation #5: Designate, Recognize and Support River-Smart Regional Intermediaries

Background

In this recommendation, the final one in this report, we identify several municipal needs that go beyond the specific content of federal and state programs, and instead emphasize the way these programs could be better communicated, offered and delivered.

Municipalities in New England have tremendous autonomy and responsibility in relation to rivers, riverside lands and river floods. They bear the primary authority for land use regulation and planning, are responsible for local-level emergency response, and maintain locally owned infrastructure like roads and bridges. New England communities also benefit from a deep culture of civic responsibility and independence. Innumerable town and city government officials and staff serve their communities knowledgeably and responsibly in ways that help their communities prepare for and respond to floods. After flood events, residents across New England repeatedly step up to help their fellow townspeople and neighboring communities recover from damage.

Yet New England communities do not by themselves have the resources or capacity to do all that is needed to become river-smart. Small towns in particular commonly have a very limited paid staff, and volunteer government. When hit by major river floods, municipalities need help to deal with the enormous scale of damage. They can become easily overwhelmed with the surge of communication and data needs, requests for help, and visiting teams of out-of-town would-be helpers. They often need outside technical expertise and financial assistance to recover effectively. They need help to plan and prepare effectively for future floods, and, as they become river-smart, they may need extra assistance to help them build new knowledge and adopt new practices.

The federal government and the New England states have programs that aim to help communities and landowners. Many of these offer important financial and technical resources. However, many municipalities, especially smaller towns, have difficulty accessing these programs. Town leaders and staff may not be experienced with the often elaborate rules for applying to or administering the programs, or may not have the technical expertise to run them. They may have limited capacity and funds to prepare long and involved applications, undertake required baseline studies, or implement complex management or regulations. And they cannot by themselves take on watershed-wide assessment, planning and action.

Even when federal and state programs and staff do direct outreach to municipalities, or offer special assistance, it is often less effective than intended. This problem can be particularly acute during and after a flood emergency. Damage and needs are often widespread, and state and federal staff are over-stretched. Locals with little training may suddenly find themselves needing to work with state and federal personnel and information systems. Emergency and post-emergency crews are often brought in temporarily, sometimes from distant parts of the region or country. They are not always aware of and sensitive to New England towns' distinct needs, responsibilities and challenges, nor to the peculiarities of New England's dynamic and varied natural environments (see Example 17, River Flood Response and Recovery, p. 68).

These situations create a disconnect between the municipalities that are on the front lines of flood planning, preparation and response, and state or federal agencies charged with providing assistance. Neither town-by-town federal and state outreach, nor increased municipal staffing is likely to solve this problem in a cost-effective way. There needs to be someone between towns on the one hand, and state and federal agencies on the other. In states outside New England, counties often play that role. But in much of New England, counties are weak; in some states, they are nonexistent.

Left to fill in the gap (sometimes) are other organizations that work in sub-state regions – areas covering a few to maybe two or three dozen towns. They operate on relatively small budgets, with just enough overhead to maintain a consistent office and a few long-term administrative staff to provide continuity. We call these crucial, often underappreciated organizations "Regional Intermediaries" – groups that can help communicate between local towns on the one hand, and state and federal agencies on the other. Successful Regional Intermediaries have one or more long-term staff who have relevant expertise in technical matters, who are able to think and act integratively to address multi-sectoral needs and problems, and who know, understand and work well with municipalities and landowners, as well as with state and federal agencies. A river-smart Regional Intermediary has the technical training and skills, knowledge of management and policy tools, and familiarity with relevant federal and state programs, to help towns assess, plan, mitigate for, and respond to river floods in river-smart ways.

The six New England states all have designated regional councils of some kind that fulfill at least some of these roles. The names and exact functions of these vary across New England, but they include Regional Planning Commissions, Regional Planning Agencies, Planning Councils, Regional Councils of Government, and Development Commissions. They are commonly given some responsibilities and some funding by state legislatures. Additional funding may come from pass-through federal funds, with transportation funding a significant source; federal, state, or nonprofit grant programs; or membership or service fees contributed by towns. These sub-state regional bodies provide a range of services that relate to the goal of becoming river-smart, including mapping, transportation planning, community development, public safety, smart growth, hazard mitigation, and environmental planning.

In some places, other entities also serve as river-smart Regional Intermediaries. These include particular federal or state agencies (see Example 20, Local Support and Partnerships, From Concept to Completion, p. 72), and some non-government organizations (see Example 21, The White River Partnership, p. 73).

Our research has shown that towns that are able to access a strong, functional river-smart Regional Intermediary are often aided in moving toward river-smart scientific assessments, planning, management, and response. We have also found that these river-smart Regional Intermediaries have knowledge and experience that can help state and federal agencies deliver more effective and successful assistance.

Municipal need #5: Integrated and ongoing assistance to become river-smart; improved delivery of related state and federal programs so they are more efficient and useful.

Municipal Need #5 Element a) Locally available agents who can provide integrated and ongoing assistance to help New England communities become river-smart.

If state and federal policy makers adopt our first four recommendations, they will provide a range of services and supports that can make a tremendous difference for New England's communities in helping them become river-smart. However, these programs need not only to be available, but also to be accessible and useful.

In order for assistance programs to be more accessible and useful, something rather less technical is required: people. Towns and cities need locally available programs and one or a few technical support staff who provide practical, useful assistance. These technical staff should be outreach agents who can become a consistent point of contact for a range of needs.

Example 17. River Flood Response and Recovery: The Practical Limits of Federal and State Government Aid

During Tropical Storm Irene, river floods impacted 223 of Vermont's 251 towns and cities, 45 severely. Thirteen towns were entirely cut off from the state road system by road and bridge collapses. More than 1500 families were displaced from their homes.

Federal and state agencies offered unprecedented response. Nonetheless, the gaps among federal, state and local action proved almost as damaging as the rivers themselves.

For example, many people, including many local town officials, suddenly tried to use the State's disaster management system. Many had little experience using it, and it was not always intuitive. As a result, some inputted data incorrectly, while others gave up trying.

Town officials found themselves overwhelmed with requests for information – from the Federal Emergency Management Agency (FEMA), the Vermont Department of Transportation, the State Police, the State Department of Health, the National Guard, and others. Often there were repeat requests.

The State's road condition information system, phone number 511, was overwhelmed, and not consistently up to date for several days. Even then, it covered only State roads, not local ones. Federal and state agencies and volunteer groups delivering supplies and services to remote rural areas often found they could not get there by the routes they planned.

When FEMA teams came into town after the storm, offering to assess damage and offer possible financial support for repair and reconstruction, they commonly brought temporary staff from other parts of the country. Many were unprepared to work with volunteer government officials, a lack of county governments, or a large number of gravel roads--all typical conditions in rural New England. Often three or more teams would come in succession to a single town, each with a slightly different set of definitions or requirements for processing claims. This caused headaches for local officials.

In many cases there were strong local relationships that towns used to recover – but even then, the gap between local, state and federal governments caused troubles. Towns that were hardest hit and least prepared received considerable help from their neighboring towns. They found out after the fact that the helping towns would have difficulty getting reimbursement from FEMA unless the two towns had a pre-existing Memorandum of Understanding. Also, many rural Vermonters with useful equipment such as tractors, dump trucks, and backhoes helped with local emergency restoration of roads, debris removal, etc. Some people sought guidance from the Vermont Agency of Natural Resources, but they found the state's river engineers were overwhelmed trying to help both municipalities and the state Department of Transportation repair hundreds of miles of roads and bridges. Then, the governor, intending to be supportive, encouraged locals to start digging gravel out of rivers. Soon, there were back hoes in rivers across the state, destructively undermining the long-term stability and adjustment processes of rivers.

These kinds of problems cannot be solved simply by better state and federal programs or staffing. As Vermont's Tropical Storm Irene After-Action report noted, "Both the federal and the State governments have limits to their response and recovery efforts and the reimbursement levels that they can achieve…. Because these limitations are not well known by municipalities and citizens… there were unrealistic expectations." In the face of inevitable limitations in federal and state capacity, an in-between set of Regional Intermediaries is often best able to fill the gaps (see Example 18).

Source: State of Vermont 2012: Tropical Storm Irene After Action Report / Improvement Plan. Final Draft, April 9, 2012. https://gmunitedway.files.wordpress.com/2012/04/ts-irene-aar-ip-2012_0409_final.pdf.

Example 18. River-Smart Regional Intermediaries Fill the Gaps: Vermont's Regional Planning Commissions During And After Irene

When communication and assistance between federal, state and local governments broke down after Tropical Storm Irene (see Example 17), Vermont's Regional Planning Commissions (RPCs) stepped into the breach. When RPC staff learned that the state road information system was not keeping up, RPCs used their technical skills and their extensive knowledge of roads and communities to get up-to-date road conditions onto user-friendly Google Maps. Soon, towns, the state police, and emergency responders were using the RPCs' maps. When communication between state agencies and local towns proved inadequate, RPC staff used their familiarity with both the state Emergency Operations Centers, and many towns' emergency plans, to facilitate smooth information flow. When RPC staff recognized that personnel from the state's Emergency Operations Center were becoming exhausted, RPCs from less hard-hit areas sent their own trained personnel to relieve them.

Soon, state and federal agencies began to request RPC assistance. Then, they formally recognized, supported, and boosted the RPC role. The Vermont Department of Transportation (VTrans) gave the RPCs official responsibility for road mapping. With support from the Governor, VTrans gave the RPCs the job of helping municipalities get needed resources to repair local roads. The State set up a central office for the RPCs called a Regional Coordination Center. The RPCs across the state set up Mutual Aid Agreements, and RPCs from less overwhelmed areas provided shared staffing for the coordination center. The Regional Coordination Center developed an assessment form and distributed updated maps and other information. The RPCs undertook other tasks: helped FEMA administer its Public Assistance Program, accompanied FEMA staff to visit local areas, coordinated meetings, and helped towns with applications for assistance. They worked with property owners who had the worst damage to find the best resources for possible buy and continued to assist for the ensuing months.

People from all levels of government recognized the invaluable role the RPCs had played. Vermont instituted a program to train three staff members from each RPC to function in an emergency. To help RPCs reduce the damage from river floods, the Agency of Natural Resources and VTrans trained RPC staff on how to deal with damage in and near rivers through their new "Rivers and Roads training" (see Example 14, p. 63). RPC staff have also attended webinars on how municipalities will be authorized to conduct emergency instream protective measures, so they can assist municipalities with this during future disasters. In the future, RPC staff may also be trained as floodplain technicians who can help review floodplain and river corridor developments and reparations. This will help rivers to be less damaging during floods, and will help head off damaging interventions into rivers before and after disasters.

Source: NADO Research Foundation 2012: Lessons learned from Irene: Vermont RPCs address transportation system recovery. Center for Transportation Advancement and Regional Development with support from the Federal Highway Administration, Washington, DC. http://www.nado.org/wp-content/uploads/2012/06/IreneVT.pdf

Assessment form developed by Vermont's Regional Planning Commissions after Tropical Storm Irene

Irene Flood Response - Regional Resource Coordination
Local Road Initial Damage Assessment Data Form *Version 4*

*****Fill out One Form for Each Damage Area*****

Town: _____ RPC: _____

Road Name/ Number and Location Description (*provide adequate detail to locate project on a map such as road name, route number, GPS coordinates (Lat, Long in dec. deg), E911 Address, Mile Marker*): _____ Town Contact: _____

_____ Title/Position: _____

_____ Recorded by: _____

Date: _____

Bridge/Culvert Number: _____ Municipal Repair Priority:

Length (feet) of Segment (for roads): _____ ☐ High ☐ Medium ☐ Low

Residences Stranded: ☐ Yes

How Many: _____

Facility Type: (*check all that apply*): ☐ Road ☐ Bridge* ☐ Culvert ☐ Other Highway

***Will a Temporary Bridge be needed before Winter? ☐ Yes Length in feet if known:** _____

Status: ☐ Closed ☐ Emergency vehicle only ☐ Open with lane/weight restriction ☐ Open, repair needed ☐ Open, Fixed

If facility is closed, is a detour route in place? ☐ Yes ☐ No

Will the detour be in place for more than one week? ☐ Yes

Damage description: _____

Have temporary repairs been made: ☐ Yes ☐ No Cost of Temporary Repairs _____

Describe temporary repairs: _____

Does Town need assistance in getting repairs started? ☐ Yes

Describe resources needed: _____

Specifically, municipalities need technical assistants who are:

Locally available and knowledgeable

- Available throughout New England, year after year, with a clear commitment to serve rural, remote and small towns
- Able to work closely with and guide municipal leaders, landowners and residents as they learn new science and best practices, perform assessments, prepare plans, implement projects, and conduct evaluations
- Knowledgeable about and respectful of the municipalities, lands, and people with whom they work
- Familiar with town ordinances, Town Meeting, voluntary government, and other New England approaches to local policy change and funding

Technically skilled and knowledgeable about river science and river-smart management

- Trained in river science; technically skilled and experienced in accessing, producing and recording relevant data
- Well versed in a range of river-smart best practices, including the complexities of and opportunities for river-smart land use management

Familiar and experienced with federal and state programs, data systems, grants, resources, and regulations, and can help municipalities navigate tasks such as:

- Preparing documents for federal and state regulations, plans, and applications, e.g. flood hazard mitigation grants
- Accessing and inputting data from and to state and federal information systems
- Reviewing floodplain development or protection plans for compliance with new river-smart regulations

Able to think and act integratively

- Can provide integrated river-smart information and technical assistance, thinking and acting across a range of sectors
- Can facilitate multi-town coordination to address river processes, land use, and flood hazard risk across watersheds

Municipal Need #5 Element b) Improved provision and delivery of state and federal programs and resources that aim to help New England communities become river-smart.

In addition to more reliable and useful local assistance, municipalities also need federal and state programs to be more attuned to local needs and conditions. After Tropical Storm Irene, this need was particularly apparent. Various state and federal agencies reached out directly to local communities and property owners, offering augmented help. However, some of these agencies sent staff who sometimes lacked knowledge of local needs, conditions, and constraints. Communication was sometimes inadequate and other times excessive, and local officials, staff and residents were frequently left with inefficient and uneven assistance, and contradictory or unclear guidance (see Example 17, River Flood Response and Recovery, p. 68).

Recommendation #5: Designate, recognize and support river-smart Regional Intermediaries to provide low-cost and no-cost technical assistance to municipalities, and to guide and assist with federal and state programs.

River-smart Regional Intermediaries are invaluable resources for New England. More than any other kind of institution, they have tremendous potential to help New England's small towns access useful, supportive assistance, resources and programs to become river-smart. By using these organizations to help New England communities become river-smart, we can avoid having to re-invent new levels of government, or new funding programs. Vermont did exactly this during and after Irene, with considerable success (see Example 18, River-Smart Regional Intermediaries Fill the Gaps, p. 69).

If Regional Intermediaries can be supported with the science, technical skills, policy tools and training to be river-smart Regional Intermediaries, they will in turn train, support and do outreach to municipalities across New England to help them, too, become river-smart. In short, supporting river-smart Regional Intermediaries more widely and more reliably would be a particularly cost-effective, adaptable way to improve New England municipalities' access to and success with river-smart flood assessment, planning, mitigation, emergency response, and recovery.

Recommendation #5 element a) Ensure that all municipalities in New England have access to a river-smart Regional Intermediary, whose mission includes low-cost service for municipalities and which has capable, reliable staff who respect towns' authorities and support towns' capacities.

States should designate river-smart Regional Intermediaries across New England. Every town and city in the six states should be assigned to a river-smart Regional Intermediary. These river-smart Regional Intermediaries should be authorized, instructed and funded to provide service to all towns in their district, including and especially small towns, while respecting their authorities and supporting their capacities.

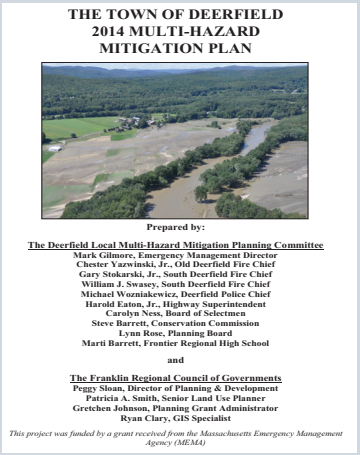
In many cases, these river-smart Regional Intermediaries will be already-existing state-designated regional councils. The Franklin Council of Regional Governments in western Massachusetts provides a strong example (see Example 19, Guiding River-Smart Hazard Mitigation Plans, p. 71). These need not be made uniform; there are many good reasons for the varying structure of regional councils in New England. It may be new, however, to assign them a primary role and function in helping municipalities become river-smart, or to require them to provide service to all towns, including very small towns, in their district. These changes may require new administrative rules at the state level, or at the level of the Regional Intermediary itself, and/or revised statutory authorities.

In states like Maine with relatively strong counties, counties may be supported to step into this role. Maine's counties already have Emergency Management Agencies, and work on health and public safety. In parts of Maine where there are no organized municipalities – something that is uncommon in the other five states – Maine's counties also provide bridge and road maintenance services, and thus are very appropriate institutions to take on the role of river-smart Regional Intermediaries in relation to transportation infrastructure.

Example 19. Guiding River-Smart Hazard Mitigation Plans: Franklin Regional Council of Governments

Towns often struggle with finding the resources and expertise to develop Hazard Mitigation Plans. It can be especially difficult if they want to include an understanding of the fluvial hazards of river floods, and to mitigate these successfully. River-smart Regional Intermediaries can help. In western Massachusetts, the Franklin Regional Council of Governments (FRCOG) has worked with 26 towns to complete Hazard Mitigation Plans.

FRCOG has been able to assist towns in applying for needed grants and hiring consultants, and has coordinated among towns to improve the impact of each Plan. Employees at FRCOG have been working especially to improve flood resiliency. Many of the Hazard Mitigation Plans in their region now include fluvial erosion hazards in their flood hazard planning and projects.



THE TOWN OF DEERFIELD
2014 MULTI-HAZARD
MITIGATION PLAN

Prepared by:

The Deerfield Local Multi-Hazard Mitigation Planning Committee
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This project was funded by a grant received from the Massachusetts Emergency Management Agency (MEMA)

In a few places, other governmental or non-profit organizations may fill the role of river-smart Regional Intermediary better than regional councils or counties, or may work in a complementary way. The Natural Resources Conservation Service is a federal agency with extensive outreach staff, and in many locations its staff are able to act, or have the potential to act, as river-smart Regional Intermediaries (see Example 20, Local Support and Partnerships, From Concept to Completion, at right). The White River Partnership, a nonprofit working in central-eastern Vermont, has played a particularly active and focused role helping municipalities and landowners in its watershed to become more river-smart, often by building extensive networks with federal, state, regional, local and non-profit organizations (see Example 21, The White River Partnership, p. 73). States may designate other organizations like these as river-smart Regional Intermediaries. These should, however, still be accountable to states' goals of providing municipalities with cost-effective assistance to become river-smart.

To ensure that Regional Intermediaries provide the needed services to help communities become river-smart, states and federal agencies should:

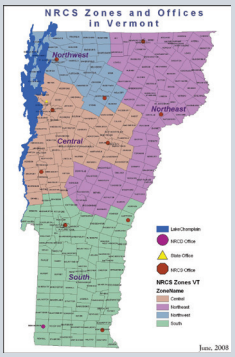
Hire and train staff whose job description includes providing assistance to towns to become more river-smart.

Train these staff in river science, fluvial hazard assessment, river-smart best management practices, river-smart planning, policy and economic tools to achieve river-smart land use and development, and evaluation of implemented programs, structures, zones, or practices. A statewide training program something like the Vermont Rivers and Roads training could be a good start (see Example 14, Vermont Rivers and Roads Program, p. 63).

Clarify the role and functions of river-smart Regional Intermediaries in relation to helping municipalities become river-smart. Suggested roles and functions include:

- Conduct or facilitate technical studies: fluvial hazard assessments, surveys, baseline studies, GIS analyses, initial designs, etc.

Example 20. Local Support and Partnerships, From Concept to Completion: Technical Assistance From the Natural Resources Conservation Service



Tropical Storm Irene Damage, West Branch Deerfield River, Readsboro Vermont. NRCS VT Engineering Staff coordinated with NRCS employees from around the country to form teams who performed damage survey reports throughout the state. In 2011, NRCS VT investigated 193 damaged sites and determined 153 of them eligible for the Emergency Watershed Program. (Photo from NRCS, Conserving Natural Resources in Vermont, January 2012).

Though a federal agency, the Natural Resources Conservation Service (NRCS) does a remarkably good job providing local-level assistance and support. Some of this support can be used for river flood mitigation and damage response. The NRCS is able to be effective at the local level because it has regional offices with staff who work hands-on in communities, and because it works closely with Conservation Districts, which are local units of government that promote voluntary conservation practices among farmers, ranchers and other land users. Often Conservation Districts are co-located with NRCS regional offices.

Partnerships among NRCS, Conservation Districts, regional, state and federal agencies, and nonprofit organizations help NRCS pool expertise, leverage funds and maintain close connections with landowners and municipalities. NRCS helps identify federal and state programs and resources that can work for towns and landowners, and helps them learn about conservation practices that can enhance property values, protect against floods, and satisfy federal and state program grant program requirements.

When floods occur, NRCS is often first on the scene, performing damage assessments that help the affected parties obtain eligibility for disaster reimbursement programs. NRCS continues to work with them throughout the recovery process, through project planning all the way to implementation.

- Facilitate river-smart municipal and multi-municipality planning, including transportation planning, flood hazard planning, emergency response planning, and economic development planning. In small towns, river-smart Regional Intermediaries may do much of the actual work conducting river-smart planning studies and preparing planning documents, though they must do this with close communication with town officials and landowners.
- Help towns prepare grant applications and other paperwork for federal or state agencies.
- Provide guidance to towns and cities on how to adapt to floodplain, stream crossing, and other river-smart regulations without undue burden; and in the development of easements, buy-outs and other voluntary approaches to land use change.
- Train municipal staff, leaders, and volunteers – for example, in river science or best management practices.
- Help evaluate river-smart structures, projects, economic development, etc. – from start to finish and beyond, to evaluation and maintenance.
- Conduct or guide outreach among town residents and property owners; assist with public communications with residents, the media, and other audiences.

Ensure that river-smart Regional Intermediaries have access to stable funding to keep core staff and programs over time. There are several ways to provide more consistent funding, including:

- Structure federal and state grant programs to ensure wider funding for the work of river-smart

Example 21. The White River Partnership: A Nonprofit River-Smart Regional Intermediary Connects Communities to Their River and to Government Resources

The White River Partnership in Vermont is a watershed-based nonprofit organization that acts as a remarkably successful river-smart Regional Intermediary. Working closely with communities, landowners, state and federal agencies, it supports environmental, social and economic benefits of resilient lands, rivers and watersheds. Stakeholders across the watershed and beyond speak highly of the Partnership's ability to navigate the complex science and policy of river management while maintaining close ties to the residents of the watershed.

Strategies of the White River Partnership:

- Studies and Mapping: The White River Partnership has assisted or completed seven geomorphic assessments of the White River Watershed.
- Outreach and Education: After Tropical Storm Irene, WRP conducted many door-to-door visits. WRP works with over 600 teachers and students each year to monitor water quality, assist on restoration projects and bring kids out into the watershed
- On-the-Ground Projects: WRP has completed over 200 restoration projects, ranging from private land bank restoration to improving local river recreation access.
- Supporting River-Resilient, People-Protective Land Use Change: After Tropical Storm Irene, the White River Partnership facilitated outside federal agency assistance with flood recovery, helped raise federal funds to improve FEMA public assistance projects, and helped towns apply for FEMA buyout funds.
- Networking: The White River Partnership works with a host of federal, state and regional agencies, as well as other nonprofits. Among these are the Green Mountain National Forest, the Vermont Agency of Natural Resources, the US Fish and Wildlife Service, and the Two Rivers-Ottauquechee Regional Commission.

A White River Partnership restoration project at Hurricane Flats Farm, VT.

whiteriverpartnership.org/

Regional Intermediaries. Ensure that Regional Intermediaries count as eligible applicants; that their administrative, support, outreach and facilitation work can be funded; and that river-smart activities are funding priorities. Also, augment flood preparedness and response grants.

- Specify that transportation funding (which is often a relatively stable and ample source of funding for regional councils) can be used for river-smart planning, construction and training – e.g. roadway fluvial hazard assessments, better culvert and bridge design, transportation plans that keep infrastructure away from fluvial hazard zones, or fluvial hazard training for transportation crews.
- Encourage river-smart Regional Intermediaries to collect small, regular membership fees from member towns that give it a small core of funding, flexibility, and a mandate to serve all the towns in their district. (see Example 22, Toward Stable Core Funding for River-Smart Regional Intermediaries, p. 74).
- Provide direct appropriations from state and federal governments for river-smart Regional Intermediaries. For example, the Massachusetts' District Local Technical Assistance program provides funding through the state budget for distribution among the state's 13 regional planning agencies for the purpose of providing technical assistance to member communities. This does not cover a large portion of the regional councils' budgets, but it gives them a small consistent funding source with which they can maintain core staff and offices. (see

Example 22. Toward Stable Core Funding for River-Smart Regional Intermediaries: Massachusetts Examples

One challenge for many regional councils, as well as for the states and municipalities they serve, is that their funding sources are unreliable and variable, coming as they do from grants and fees. Because much of the work of regional councils is funded by grants, many of their programs last only for a few years. Regional councils that depend on fees have a different problem: they may end up assisting disproportionately those municipalities that pay the largest amount in fees – often leaving the smaller, more remote communities with little help.

River-smart Regional Intermediaries with at least a small amount of stable funding can maintain a reliable, consistent office, a few core administrative and technical staff, and creative or important programs even when no other funding is available. They can also more reliably maintain service to small communities with few resources of their own – especially when their small but stable core funding comes with a mandate to serve those communities.

For example, the Franklin Regional Council of Governments in western Massachusetts (see Example 19) is able to fund 5% of its budget from membership fees. This supports some core staffing, as well as providing resources to projects that don't have other funding sources. It also makes the Franklin Regional Council of Governments accessible and accountable to every one of its members.

In Massachusetts the generic term for regional council is "regional planning agency." Every regional planning agency in Massachusetts has another reliable small pot of money. In 2006, the Massachusetts legislature recognized the important role of the thirteen regional planning agencies in assisting the Commonwealth's 351 cities and towns, and created a fund called the District Local Technical Assistance. The legislature has allocated a small but crucial amount of reliable state funding to this district local assistance fund every year since.

Currently, a total of $2 million per year is distributed among the state's thirteen regional planning agencies so they can provide technical assistance to member communities. Most regional planning agencies receive $150,000 base funding, with an additional (approximately) $1 million divided among them according to population and number of towns in each region. The regional planning agencies use the money to provide member cities and towns with technical assistance in two key areas: sustainable development and preservation, and regional collaboration in service delivery or procurement. Both of these are consistent with helping municipalities become more river-smart, and the reliable state funding can help carry these programs over time, and even into remote rural areas.

Example 22, Toward Stable Core Funding for River-Smart Regional Intermediaries, p. 74).

Recommendation #5 element b) Use river-smart Regional Intermediaries to guide and assist with delivery of flood assessment, planning, mitigation and response services to local governments and landowners, and to gather and understand information on local needs and conditions.

Federal and state agencies that do not have a presence in substate regional offices should coordinate with and through river-smart Regional Intermediaries in their outreach to municipalities.

Federal and state programs that aim to assist or guide local municipalities and property owners in becoming more river-smart should work with and through river-smart Regional Intermediaries as much as possible. They will be better attuned to local needs and capacities, more effective, and more efficient in terms of costs and personnel. This is true with a wide range of activities – educating towns about new regulations, training town staff with new skills, assisting towns with planning or river-smart economic development, getting feedback on new policies, facilitating inter-town discussions, promoting grant programs, etc.

Coordinating with and through river-smart Regional Intermediaries is especially important during and after river flood emergencies. At these times, federal and state agencies temporarily ramp up outreach and support to municipalities and local property owners – but to do so they necessarily bring in staff who have much less familiarity with local New England towns and environments. In this situation, it is essential that they build on the knowledge, skills and relationships of someone who has ongoing experience working with local communities. For example, when the Federal Emergency Management Agency sets up regional assistance centers after declared emergencies, outreach to communities would be much more effective and efficient, both for the federal agents and for local town officials, if they ask an effective river-smart Regional Intermediary to help guide and facilitate their work (see Example 18, River-smart Regional Intermediaries Fill the Gaps, p. 69).

Federal and state emergency responders should plan ahead to use river-smart Regional Intermediaries to deliver federal and state emergency response and post-emergency support. They should formalize expectations for this coordination and assistance as part of state emergency planning.

State emergency plans should include the role of river-smart Regional Intermediaries. This will enable states and collaborating federal agencies to clarify the role of river-smart Regional Intermediaries, and hammer out the details, with forethought. Particular functions, supported by modest funding, can be set up ahead of time through Memorandums of Understanding and Memorandums of Agreement. Technical requirements such as communication systems and networks can be acquired or built. Federal and state agencies should support these functions as needed with additional training and resources.

Some possible emergency tasks that could be assigned formally to river-smart Regional Intermediaries in state emergency plans include:

- Conduct initial emergency outreach and support to towns that have been cut off from transportation routes.
- Assess local roads, needs, priorities and input into databases. Prepare for a backup data gathering system in case databases break down or software becomes unusable.
- Serve as a communication conduit between federal agencies and local communities during and after emergencies.
- Accompany federal and state officials when they go out to local towns and properties, helping to orient them and explain their work to local residents.
- Keep track of different crews from different agencies that go out to communities, so that federal and state agency staff know who else has been to which communities, and what they have said and done. Act as a centralized clearinghouse of action and information in the local region.

- Conduct emergency environmental assessment, guidance and permitting, or support municipal officials to do so.
- Provide support to local emergency managers so that as they suddenly have to step up to large and wide sets of responsibilities, they are able to fulfill these functions confidently and successfully.

In addition to using Regional Intermediaries to deliver their programs, federal and state agencies should consult with river-smart Regional Intermediaries on an ongoing basis, to shape federal and state policies, programs and resources that aim to assist New England municipalities.

Federal and state agencies should consult with river-smart Regional Intermediaries to help inform and shape their programs and resources that are targeted to assist New England towns and cities. This is true even for many programs and resources that may not be conceived as related to river floods – for example, agricultural and forestry programs, which shape riverside land use; economic development programs, which need to avoid development in fluvial hazard zones and support development in river-smart locations; transportation programs, so transportation infrastructure is built to be resilient to river floods; and fish and wildlife programs, which should work to protect river habitat, and support aquatic, riparian and floodplain species in ways that can accommodate and support natural river dynamics.

In all these cases, river-smart Regional Intermediaries will recognize the relation between these programs and community river flood resilience, and be able to help advise. Other agencies that have statewide or federal expertise on river flood hazards will also will be essential. The crucial contribution of River-smart Regional Intermediaries will be to provide the intimate knowledge and experience of working with local communities and landowners that can guide state and federal programs, regulations and resources to become more efficient, effective with, and accessible to local communities.

Agencies should use feedback from Regional Intermediaries to revise, target, streamline and support these programs and resources so they are as effective and accessible as possible in helping New England communities become river-smart.

It may be that funding and working with a central state-wide coordinating office of Regional Intermediaries in each of the six states, like Vermont's Regional Coordination Center created after Tropical Storm Irene could be particularly effective for this purpose (see Example 18, River-smart Regional Intermediaries Fill the Gaps, p. 69).

V. Conclusion

In New England, we love our rivers – and with good reason. They bring fresh water, beautiful scenery, places to fish and boat and swim, thriving wildlife and plants, and familiar sounds of babbling or flowing sounds. They powered our region's industrialization and have helped build and sustain its important agricultural, recreational, and tourist industries. Many of our communities and many of our favorite places are along the banks of a stream or river.

Yet one aspect of our rivers that we have too often failed to understand, or at least to remember, is that they flood – and when they flood, they have tremendous power. We have not sufficiently anticipated or prepared for the destructive effects of powerful river floods. For this reason river floods have frequently had damaging consequences for the buildings, infrastructure and other investments we have placed across streams or on riverside lands. Recently, policymakers have voiced concerns about the coastal flooding and hurricanes that may come with climate change, about heat waves and snow – but as a region and in our hundreds of communities we are still failing to plan ahead for the times when our familiar rivers and streams will become raging torrents. Such times are likely to come more often in the future. Just as climate change threatens sea level rise, it also promises to bring larger and more frequent river floods to inland areas as well as to coastal regions, as extreme weather events like hurricanes and rain-on-snow events become more frequent and more extreme.

It is time we learn, understand, prepare and act. We must all become much more river-smart.

This report has aimed to give the residents, community leaders, government agency staff, and policy makers critical information and guidance that can help.

Chapters 1 through 3 provided background information. Chapter 1 provided important historical context within which to understand New England's river floods. It had two crucial lessons: river floods are common, not infrequent and rare; and we have made them more destructive by confining river channels and by building so much infrastructure in and along streams.

Chapter 2 provided a user-friendly overview of the science of fluvial geomorphology, a science that explains the ways that rivers move, and why and how they can become destructive to our homes, communities and investments. The chapter included 16 key insights about river hazards that come out of this river science, and three core lessons for science and management. Keep this chapter and its insights as an easy reference.

Chapter 3 provided background on governance in New England for rivers and riverside lands. It emphasized the strengths and challenges of our New England system of relatively autonomous local governments, which includes over 1500 towns and cities, many with participatory Town Meetings and largely volunteer governments. The chapter also summarized the strengths and challenges of federal and state agencies in meeting New England's communities' need to become more river-smart. In both local communities and in federal and state government agencies, strengths and the challenges are equally great. We finished the chapter with an overview of our own research, in which seven different organizations showed us what is possible despite the challenges. If you, too, are working to find ways to move your community or state toward better protection from damaging river floods and are feeling discouraged by the challenges, you may want to spend some time looking at the stories of these and similar organizations. They are truly inspiring. Details on many of their efforts are featured in Examples in Chapter 4, and several will have more detailed profiles posted on our website, https://extension.umass.edu/riversmart.

The heart of our effort is in Chapter 4. Our five target recommendations in Chapter 4 provided guidance. We suggested ways federal and state policies and programs can do a better job of helping New England communities to become river-smart.

We chose our recommendations based on four criteria: they would make federal and state policy significantly more effective and helpful to New England residents, landowners and communities in their efforts to become river-smart; they would require relatively little additional money; they would require relatively limited regulatory change; and they were general enough to be adapted to different state, regional and local contexts.

If you are a community leader, a government agency staff person, a policy maker, or just someone concerned about rivers or the threat of river flood damage, we invite you to take our ideas and adapt them for your needs. Use them to advocate for new and refined policies and programs that will help you and others make your state, community, region or property more river-smart. Our ideas are built on those of many other people, and we hope this report will become another step and building block, a resource for anyone and everyone in the region.

Though the recommendations are intentionally general, we know that often it is hard to imagine how to do something without far more specific guidance. Embedded in each of the recommendations were several Examples. The Examples show how someone in New England is doing one of the things we have recommended. Each is built on our research and very helpful staff and community leaders who helped us build their profile. In some cases, you may be able to follow their example closely. In other cases, you will quickly realize its approach will not work in your community, region or state. In that case, use it for inspiration, and create your own approach.

We remain inspired by the many people we have met and talked to in the development of our research and this project. Rivers are at the heart of New England, and by becoming river-smart we can thrive alongside them for centuries to come.

The Bridge of Flowers in Shelburne Falls, Mass. This photo highlights just one of the many riverside landscapes that define New England communities. In contrast to the serenity shown in this picture, during Tropical Storm Irene in August 2011, the raging Deerfield River nearly filled the bridge's arches. Because the bridge was built well to pass water, sediment and debris, it remained whole, but the torrent caused significant damage to riverside properties. By helping New England communities to become river-smart, we can ensure that when our beloved rivers flood, more of our homes, buildings and infrastructure remain resilient, and the region's rivers support rather than ravage the iconic places and landscapes that we love in New England.

Summary of Target Recommendation #1

Develop Fluvial Hazard Assessments

Recommendation:

Develop and implement fluvial hazard assessment, mapping, and user access systems across the New England states.

(See page 38).

Recommendation elements:

Develop and implement fluvial hazard assessment protocols, systems for implementation, and user-friendly maps and information portals.

Summary of Target Recommendation #2

Upgrade Vulnerable Stream Crossing Infrastructure

Recommendation:

Support upgrades of vulnerable stream crossings across the six New England states

(See page 48).

Recommendation elements:

a) Improve stream crossing regulatory standards to support upgrades, be consistent across agencies, and allow site-specific flexibility (well under way in New England)

b) Streamline permit and funding processes and requirements, and incentivize replacing vulnerable and damaged crossings with upgrades

c) Develop and make available easy-to-follow design templates and guidelines for upgraded crossings which will receive quick permitting and funding review and high likelihood of approval

d) Develop and support an accessible inventory and database of stream crossings that identifies vulnerable crossings

e) Increase and diversify funding for stream crossing upgrades.

Summary of Target Recommendation #3

Support River-Smart Planning and Mitigation

Recommendation:

Support municipal efforts to prepare for and mitigate river flood hazards through planning and land use

(See page 55).

Recommendation elements:

a) Support municipal, multi-municipality, regional and state hazard planning that addresses river flood hazards

b) Enable and promote a diverse menu of mechanisms for communities to achieve river-smart conservation, mitigation, and development; support with technical, financial and legal assistance.

c) Ensure that support is available to communities on an ongoing basis, until their plans are fully implemented.

Summary of Target Recommendation #4

Provide Outreach and Training on River Dynamics and River-Smart Practice

Recommendation:

Prepare and disseminate outreach materials and training on river dynamics, lessons for river flood hazards, and river-smart best management practices.

(See page 61).

Recommendation elements:

a) Train transportation work crew personnel in New England on river dynamics and river-smart best management practices

b) Produce easily understandable outreach materials on river dynamics and practical lessons for land management; disseminate widely, especially to land use decision makers

c) Prepare in-depth outreach materials; create, publicize and maintain systems to deliver these quickly and efficiently upon request

Summary of Target Recommendation #5

Designate, Recognize and Support River-Smart Regional Intermediaries Practice

Recommendation:

Designate, recognize and support river-smart Regional Intermediaries to provide low-cost and no-cost technical assistance to municipalities, and to guide and assist with federal and state programs.

(See page 70).

Recommendation elements:

a) Ensure that all municipalities in New England have access to a river-smart Regional Intermediary, whose mission includes low-cost service for municipalities and which has capable, reliable staff who respect towns' authorities and support towns' capacities.

b) Use river-smart Regional Intermediaries to guide and assist with delivery of flood assessment, planning, mitigation and response services to local governments and landowners, and to gather and understand information on local needs and conditions.

Notes

1. National Oceanic and Atmospheric Administration, "Preliminary Hurricane/ Tropical Storm Irene Weather Summary for the North Country," National Weather Service Forecast Office, September 2, 2011. http://www.erh.noaa.gov/btv/events/Irene2011/.

2. For some of the best collections of images and stories about Tropical Storm Irene's destruction in New England, especially Vermont, see: Free Press Staff, "An Irene Narrative: Journey through Devastation in Vermont," Burlington Free Press, September 4, 2011, http://archive.burlingtonfreepress.com/interactive/article/20110904/NEWS07/309040001/An-Irene-narrative-Journey-through-devastation-Vermont; Burlington Free Press, *The Year of the Storms: Vermont's Remarkable Experiences in 2011*, Burlington, VT: Pediment Publishing, 2011; M. Dickey Drysdale, *The Wrath of Irene Deluxe: Vermont's Imperfect Storm of 2011,* CreateSpace Independent Publishing Platform, 2012; Patrick Johnson,"Irene Has Gone but Problems Remain; Western Massachusetts Towns Waiting to Get Full Measure of Damage," Mass Live, August 29, 2011, http://www.masslive.com/news/index.ssf/2011/08/irene_has_gone_but_problems_re.html; "Power Outages, Flooding from Irene in Massachusetts," Associated Press, August 28, 2011, http://usatoday30.usatoday.com/news/nation/story/2011-08-28/Power-outages-flooding-from-Irene-in-Massachusetts/50169538/1.

3. See e.g. John Appleton, "Hurricane Irene flooding devastates several Western Massachusetts farm crops," August 30, 2011, http://www.masslive.com/news/index.ssf/2011/08/hurricane_irene_flooding_devas.html.

4. Sacha Pealer, "Lessons from Irene: Building Resiliency as We Rebuild," Vermont Agency of Natural Resources, January 4, 2012, http://www.anr.state.vt.us/anr/climatechange/Pubs/Irene_Facts.pdf.

5. For more background on fluvial geomorphology, see Vermont Agency of Natural Resources, "River Dynamics 101 - Fact Sheet," River Management Program, June 14, 2005, http://www.watershedmanagement.vt.gov/rivers/docs/rv_river_dynamics_101.pdf; Ellen Wohl, *Rivers in the Landscape: Science and Management*, Wiley-Blackwell, 2014; Gary J. Brierley and Kirstie A. Fryirs. *Geomorphic Analysis of River Systems: An Approach to Reading the Landscape*, West Sussex, UK: Wiley-Blackwell, 2012; Ellen Wohl, "Time and Rivers Flowing: Fluvial Geomorphology since 1960," *Geomorphology* 216 (July 2014): 263–82; Ann Smith, Abbey Willard, Linda Henzel, and Mike Kline, "Living in Harmony with Streams: A Citizen's Handbook to How Streams Work," Friends of the Winooski River, White River Natural Resources Conservation District, Winooski Natural Resources Conservation District, 2012; http://www.winooskiriver.org/images/userfiles/files/Stream%20Guide%201-25-2012%20FINAL.pdf.

6. See e.g. R.C. Walter, and D.J. Merritts, 2008, Natural Streams and the Legacy of Water-Powered Mills, *Science* 319 (5861): 299-304.

7. Eve Vogel and Alexandra Lacy, "New Deal versus Yankee Independence: The Failure of Comprehensive Development on the Connecticut River, and Its Long-Term Consequences," *The Northeastern Geographer* 4 (2), 2012: 66–94. For more information on several of these past New England floods see: http://www.floodsafety.noaa.gov/states/ma-flood.shtml.

8. See e.g. Motoyoshi, Tadahiro, "Public Perception of Flood Risk and Community-Based Disaster Preparedness," in S. Ikeda, T. Fukuzono, and T. Sato, Eds. *A better integrated management of disaster risks: Toward resilient society to emerging disaster risks in megacities.* Terra Scientific Publishing Company & National Research Institute for Earth Science and Disaster Prevention, 2006, 121–34, https://www.terrapub.co.jp/e-library/nied/pdf/121.pdf.

9. Department of Environmental Conservation, Water Quality Division, "Options for State Flood Control Policies and a Flood Control Program," Waterbury, VT: Vermont Agency of Natural Resources, February 1999, http://www.watershedmanagement.vt.gov/rivers/docs/rv_act137.pdf.

10. Much of attention in flood management and control has been on controlling or reducing flood risk. But in recent years there has been increasing emphasis on the notion that no matter what we do, there is always some risk left – some "residual risk" (see e.g. Ludy, Jessica and Kondolf, G. Matt 2012: "Flood risk perception in lands 'protected' by 100-year levees," *Natural Hazards* 61: 829-842; Carter, Nicole, Flood risk management: Federal role in infrastructure, CRS Report for Congress, Order Code RL33129, 2005, http://digital.library.unt.edu/ark:/67531/metacrs7915/m1/1/high_res_d/RL33129_2005Oct26.pdf.) Our report places more emphasis on the tangible, physical processes of river dynamics than on abstract concepts of risk and residual risk, but our analysis here of what happens when people try to armor rivers and streams helps to explain some of why there is always residual risk.

11. U.S. Geological Survey, "100-Year Flood-It's All About Chance. Haven't We Already Had One This Century?" U.S. Department of the Interior, April 2010, http://pubs.usgs.gov/gip/106/pdf/100-year-flood-handout-042610.pdf.

12. Federal Emergency Management Agency, "Flood Zones," FEMA, April 26, 2015. http://www.fema.gov/flood-zones.

13. There are also considerable technical uncertainties with these numbers, especially for less common floods, and especially as the climate continues to change.

14. Frumhoff, P.C., J.J. McCarthy, J.M. Melillo, S.C. Moser, and D.J. Wuebbles, "Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions," Synthesis report of the Northeast Climate Impacts Assessment (NECIA), Cambridge, MA: Union of Concerned Scientists (UCS), 2007.

15. Data from NASA Goddard Institute for Space Studies, New York, NY, accessed via the website: "Updating the Climate Science: What Path is the Real World Following?" Makiko Sato & James Hansen, Columbia University Earth Institute, http://www.columbia.edu/~mhs119/.

16. Weider, K. and D.F. Boutt, Heterogeneous water table response to climate revealed by 60 years of ground water data, *Geophysical Research Letters*, 37 (L24405), 2010.

17. See note 5.

18. Bierman, Paul, Lini, Andrea, Zehfuss, Paul and Church, Amy 1997: Postglacial Ponds and Alluvial fans: Recorders of Holocene Landscape History, *GSA Today* 7(10): 1-2; Kline, Michael, and Barry Cahoon, "Protecting River Corridors in Vermont," *Journal of the American Water Resources Association* 46 (2), 2010: 227–36.

19. Vogel and Lacy, note 7.

20. Understanding this constant geomorphic change is important for habitat monitoring, too. See Poole, Geoffrey C., Frissell, Christopher A., and Ralph, Stephen C., "In-Stream Habitat Unit Classification: Inadequacies for Monitoring and Some Consequences for Management," *Journal of the American Water Resources Association* 33(4), 1997: 879–96.

21. The general stability will be maintained even as meanders and other features shift because while some parts of the river increase their meanders and braids, others will shorten or lose them. Processes that shorten meanders include, for example, when some meanders get so wide that adjacent curves join, creating a shortcut where the water flows instead. The abandoned meander, no longer connected to the stream channel, is called an oxbow lake. Alternatively, sometimes lower-valley rivers can break through the sediments in their own flood plains and form a shorter channel, as New Hampshire's Suncook River did, described in Example 1, p. 11.

22. See e.g. Wohl, E. 2014, A legacy of absence: Wood removal in US rivers. *Progress in Physical Geography*, October 2014 vol. 38 (5): 637-663.

23. This section was informed in large part by Department of Environmental Conservation, "Flood Hazard Area and River Corridor Protection Procedure," Vermont Agency of Natural Resources, October 6, 2014. http://floodready.vermont.gov/sites/floodready/files/documents/2014-10-06%20%20Final%20Draft%20Flood%20Hazard%20Area%20and%20River%20Corridor%20Protection%20Procedures.pdf.

24. "Room for the river" or "space for the river" has become a key policy in the Netherlands, which long managed its flood-prone lands by trying to confine and straighten its rivers. The phrase has been taken up in many other countries as well. See e.g. Climatewire, "How the Dutch Make 'Room for the River' by Redesigning Cities," Scientific American, January 20, 2012, http://www.scientificamerican.com/article/how-the-dutch-make-room-for-the-river/; Warner, Jeroen, Jeroen Frank Warner, Arwin van Buuren, and Jurian Edelenbos, Eds., *Making Space for the River: Governance Experiences with Multifunctional River Flood Management in the US and Europe,* IWA Publishing, 2013.

25. "Otter Creek," The Connecticut River Watershed Council, The Conservation Law Foundation, 2012, https://www.youtube.com/watch?v=frJFJMfPMd4.

26. For example: We can slow runoff even before it gets to streams and encourage infiltration, by minimizing impermeable surfaces and removing drainage ditches. We can plant vegetation along stream banks and in riverside floodplains and riparian areas. We can restore deepened, incised channels by raising their beds and reconnecting them with their floodplains. We can even re-shape river channels to stop head cuts or to re-create meanders and braids (though this can be very costly and must be done with some humility, as rivers do not always cooperate in following our constructed natural paths). We can remove old dams that constrain channel movements, and at the same time allow beavers to create small-scale storage in a diversity of places. See Department of Environmental Conservation, "Flood Hazard Area and River Corridor Protection Procedure," Vermont Agency of Natural Resources, October 6, 2014, http://floodready.vermont.gov/sites/floodready/files/documents/2014-10-06%20%20Final%20Draft%20Flood%20Hazard%20Area%20and%20River%20Corridor%20Protection%20Procedures.pdf.

27. Insights from UMass professor Anita Milman and postdoc Ben Warner, and from the Massachusetts Department of Ecological Restoration's Tim Chorey, all of whom were also doing research on New England communities' perspectives in relation to flood risk and river-smart development, were particularly helpful. See e.g. Anita Milman & Benjamin Warner, The Interfaces of Public and Private Adaptation: Lessons from Flooding in the Deerfield River Watershed, *Global Environmental Change*, 2015, (36):46-55, and Mass Division of Ecological Restoration: Culvert Replacement Survey, at: http://www.cmrpc.org/mass-division-ecological-restoration-culvert-replacement-survey. All interpretations in this report are our own.

28. Over 150 towns in New England have fewer than 500 people, and almost one-third of all municipalities in the region have fewer than 2,000.

29. Investigations of the Creating Resilient Communities group, the Vermont Rivers Program, and the White River Partnership were part of the RiverSmart Communities project funded by the UMass Center for Agriculture, Food and the Environment. Investigations of the New Hampshire Post-Incident Recovery Response Team / US Army Corps of Engineers Silver Jackets, the Natural Resources Conservation Service, and the North Atlantic Aquatic Connectivity Collaborative were part of the RiverSmart Communities and Federal Collaborators project, funded by the U.S. Army Corps of Engineers Institute for Water Resources. We learned about the Franklin Regional Council of Governments through our work on the other projects, especially through our work with the Creating Resilient Communities group.

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Cover photo: Christopher Condit, John Fellows and Massachusetts Geological Survey, 9/18, 2011.

Page 8: North Adams Transcript, provided courtesy Paul W. Marino, North Adams local historian, used by permission from http://paulwmarino.org/.

Page 9: left- Irene Images, Vermont Rivers Program; right – "Destroyed land near Hancock, VT," Lars Grange and Mansfield Heliflight, 8/31, 2011, at http://www.mansfieldheliflight.com/flood/.

Page 10: Irene Images, Vermont Rivers Program.

Page 11, Example 1: top- Vermont History Explorer, Vermont Historical Society, at https://vermonthistory.org/explorer/vermont-az/vermont-ef/203-floodof1927az; bottom left – USDA Farm Service Agency; bottom right – Google Maps. For more on the Suncook River avulsion see: http://des.nh.gov/organization/divisions/water/wmb/rivers/suncook-river.htm.

Page 12: "More damage and a destroyed house along Route 100," Lars Grange and Mansfield Heliflight, 8/31, 2011, at http://www.mansfieldheliflight.com/flood/

p. 14: "Route 4 / Route 100 South of Killington completely destroyed," Lars Grange and Mansfield Heliflight, 8/31, 2011, at http://www.mansfieldheliflight.com/flood/

Page 16, Example 2: left - Roland Schneider, in Vermont Long-Term Disaster Recovery Group, "We're going to get it done: Vermont's Response to Tropical Storm Irene," The Vermont Disaster Relief Fund, www.VermontDisasterRecovery.com; right – Jerry LaBlond, The Herald, Randolph, VT, at http://photo.ourherald.com/flood2011.

Page 16, bottom right: Watershed diagram by Christine Hatch and Eve Vogel.

Page 18: Floodplain diagram by Christine Hatch.

Page 20: Upper right: Vermont Rivers Program (3 stages of a multi-stage used in many documents, e.g. River Corridor Protection and Management Fact Sheet, at http://dec.vermont.gov/sites/dec/files/wsm/rivers/docs/rv_rcprotectmanagefact-sheet.pdf), adapted by Christine Hatch and Aayushi Mishra; bottom right – White River: George Springston, in Vermont Rivers Program and Floodready Vermont, at http://floodready.vermont.gov/flood_protection/river_corridors_floodplains/river_corridors.

Page 21: top left: Noah Slovin; middle right: Todd Menees, Vermont Rivers Program; bottom left: Christine Hatch.

Page 24: Timothy Dexter, Wikimedia, 2014: https://en.wikipedia.org/wiki/New_England_town.

Page 27: Amy Wildt, in Vermont Long-Term Disaster Recovery Group, "We're going to get it done: Vermont's Response to Tropical Storm Irene," The Vermont Disaster Relief Fund, p. 12, www.VermontDisasterRecovery.com.

Page 32: top - White River Partnership, 2012, http://whiteriverpartnership.org/2012-accomplishments/. Bottom: NRCS Massachusetts, 2011, http://www.nrcs.usda.gov/wps/portal/nrcs/detail/ma/newsroom/releases/?cid=nrcs144p2_014175.

Page 36, Recommendation #1 Summary photo: Alex Schwartz, Cassie Tragert, Cassandra Zawadski and Gillian Gunderson, 2015.

Page 38, Example 3: top – Vermont Natural Resources Atlas. http://anrmaps.vermont.gov/websites/anra/. ; bottom - Gomez & Sullivan in association with Parish Geomorphic, Draft Final Channel Management and River Corridor Protection Plan,

Walloomsac River and Roaring Branch, Bennington County, Vermont, December, 2007, p. 26. This and other Vermont stream geomorphic assessments are on line at: https://anrweb.vt.gov/DEC/SGA/finalReports.aspx.

Page 40, Example 4: Stream Geomorphic Sensitivity, Walloomsac River and Roaring Branch, Bennington County, Vermont; FEMA Flood Insurance Rate Maps Panels 0411D and 0413D, available at: https://msc.fema.gov/portal. Figure adaptations by Eve Vogel, Christine Hatch, and Aayushi Mishra.

Page 43, Example 5: top left- Inter-fluve Inc.; top right- Paul Nguyen; both photos in Massachusetts Division of Ecological Restoration, Massachusetts Stream Crossing Handbook, 2012, p. 10, available at: http://www.mass.gov/eea/docs/dfg/der/pdf/stream-crossings-handbook.pdf; bottom - Vermont Agency of Natural Resources/Vermont Agency of Transportation.

Page 44, Example 6: Graphic adapted by Joe Shoenfeld, Eve Vogel and Aayushi Mishra from Carrie Banks. For more on culvert replacement costs from the studies referenced in this Example, see Economic Benefits from Aquatic Ecological Restoration Projects in Massachusetts, Massachusetts Department of Ecological Restoration, 2015, at: http://www.mass.gov/eea/docs/dfg/der/pdf/summary-of-der-economic-benefits-studies-all-phases.pdf; Economic & Community Benefits from Stream Barrier Removal Projects in Massachusetts, Massachusetts Department of Ecological Restoration, 2015, at: http://www.mass.gov/eea/docs/dfg/der/pdf/phase-iii-benefits-from-stream-barrier-removal-projects.pdf; and Jessica Levine, An Economic Analysis of Improved Road-Stream Crossing, The Nature Conservancy, Adirondack Chapter, 2013, at: http://www.nature.org/ourinitiatives/regions/northamerica/road-stream-crossing-economic-analysis.pdf. For Becket case study see Amy Singler and Carrie Banks, Massachusetts Stream Crossing Case Studies, 2015, available at: http://massriversalliance.org/wp-content/uploads/2015/10/MassStreamCrossingCaseStudiesAmRivers-DER10-13.pdf.

Page 47, Example 8: left - North Atlantic Aquatic Connectivity Collaborative, Prioritizing Crossings for Assessment, available at: https://www.streamcontinuity.org/assessing_crossing_structures/prioritizing_crossings.htm; right – Vermont Agency of Transportation and the Vermont Regional Planning Commissions, VTCULVERTS, available at: http://vtculverts.org/.

Page 49, Example 9 – Christine Hatch and Marie-Francoise Hatte.

Page 51, Recommendation #3 Summary: FloodReady Vermont, "Protect River Corridors and Floodplains," available at: http://floodready.vermont.gov/flood_protection/river_corridors_floodplains.

Page 53: Vermont Agency of Commerce and Community Development, in Environmental Protection Agency, Office of Sustainable Communities Smart Growth Program, "Planning for flood recovery and long-term resilience in Vermont: Smart Growth Approaches for Disaster-Resilient Communities," EPA 231-R-14-003, July 2014, p. 13, available at: https://www.epa.gov/sites/production/files/2014-07/documents/vermont-sgia-final-report.pdf.

Page 56, Example 10: Sharon, VT Town Plan, 2015, available at: http://www.sharonvt.net/allselectboardminutes/doc_download/483-sharon-town-plan-adopted-apr-6-2015.html.

Page 57, Example 12: Figure by Eve Vogel, Joe Shoenfeld and Aayushi Mishra.

Page 58, Example 13: left - Vermont Department of Environmental Conservation, River Corridor and Floodplain Management Program and Shoreland Protection Program Biennial Report to the General Assembly Pursuant to Act 110, January 2015, available at: http://floodready.vermont.gov/sites/floodready/files/documents/Act%20110%20Legislative%20Report%20January%202015.pdf; right - Flood Ready Vermont: River corridors, at http://floodready.vermont.gov/flood_protection/river_corridors_floodplains/river_corridors.

Page 63, Example 14: Vermont Rivers and Roads Training Program Update April 2, 2014, http://legislature.vermont.gov/assets/Documents/2014/WorkGroups/House%20Fish%20and%20Wildlife/Improving%20the%20Quality%20of%20State%20Waters/Rivers%20and%20RoadsTraining%20Program/W~Shayne%20Jaquith~VT%20Rivers%20and%20Roads%20Training%20Program%20Update~4-2-2014.pdf.

Page 64, Example 15: Noah Slovin; Example 16, Massachusetts Office of Coastal Zone Management and Massachusetts StormSmart Coasts.

Page 65, Recommendation #4 Summary: Massachusetts Metropolitan Planning Organization Regions, available at: http://www.ctps.org/drupal/data/html/programs/public_involvement/P3_images/Mass-MPOsFINAL-01.jpg.

Page 69, Example 17: John Lazenby, in Vermont Long-Term Disaster Recovery Group, "We're going to get it done: Vermont's Response to Tropical Storm Irene," The Vermont Disaster Relief Fund, p. 9, www.VermontDisasterRecovery.com.

Page 70, Example 18: Both images from NADO Research Foundation 2012: "Lessons learned from Irene: Vermont RPCs address transportation system recovery," Center for Transportation Advancement and Regional Development with support from the Federal Highway Administration, Washington, DC, available at: https://www.nado.org/wp-content/uploads/2012/06/IreneVT.pdf.

Page 71, Example 19: Town of Deerfield, Massachusetts.

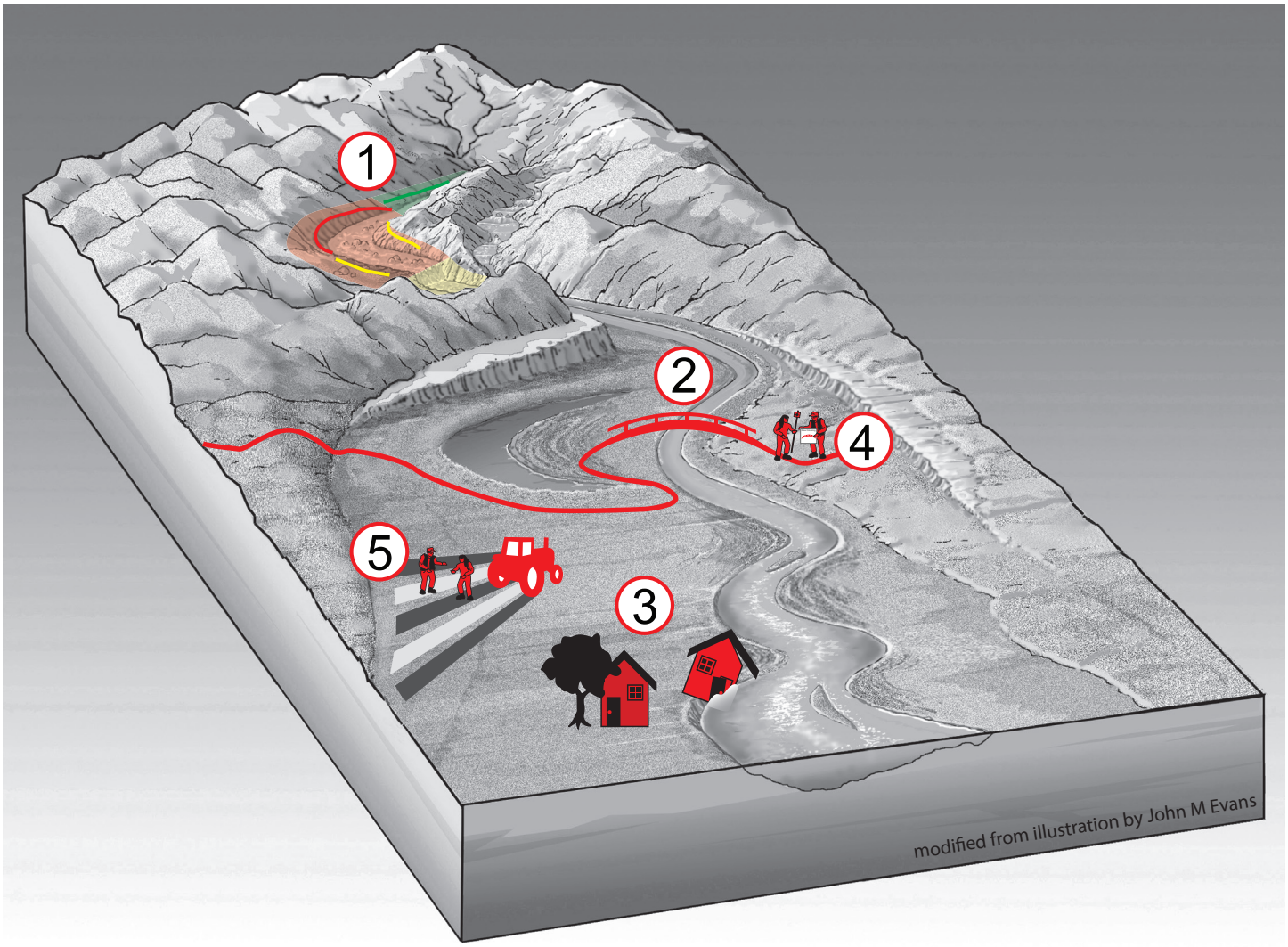
Page 72, Example 20: Photo - NRCS, Conserving Natural Resources in Vermont, January 2012, available at: http://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1256847&ext=pdf; map - NRCS Zones and Offices in Vermont, available at: http://www.nrcs.usda.gov/Internet/FSE_MEDIA/stelprdb1083444.jpg.

Page 73, Example 21: Nicole Gillett.

Page 78: Joe Shoenfeld.

Inside back cover: Diagram – modified by Christine E. Hatch from illustration by John M. Evans.

Back cover: Diagram – John M. Evans, Scientific Illustrator.



Back cover: This river process diagram was made especially for the RiverSmart Communities project to illustrate a variety of river processes that shape rivers and their landscapes from mountain headwaters to valley floodplains. You can get more information at https://extension.umass.edu/riversmart/river-processes.

Here, the added illustrations highlight our five report's five policy recommendations as they might be put into practice:

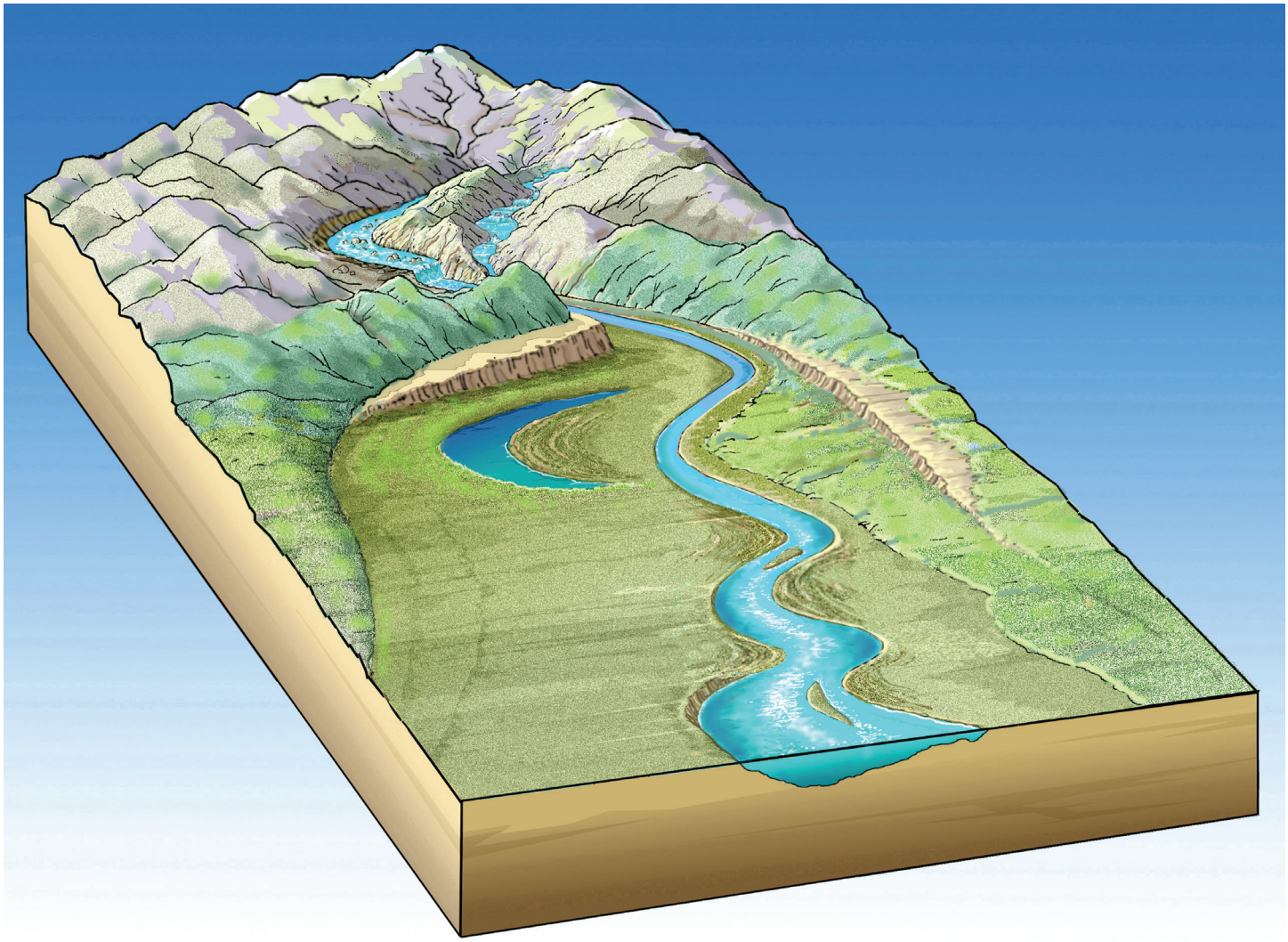
#1 Develop Fluvial Hazard Assessments – Fluvial hazards are mapped in this area as follows: Green shading upstream of the meander bend is a reach with low vulnerability, orange shading indicates a reach with high vulnerability to fluvial erosion, and yellow shading, downstream of the bend, is a reach with moderate vulnerability to erosion or deposition. More detailed assessment of streambank stability designates banks as already actively adjusting (red lines), having erosion or deposition potential (yellow lines), or stable (green line).

#2 Upgrade Vulnerable Stream Crossing Infrastructure – This road used to go over a pipe culvert which often became blocked or failed. Now, the culvert has been replaced with an open-bottomed bridge that easily passes water, sediment and debris, and provides good aquatic habitat.

#3 Support River-Smart Planning and Mitigation – One of these houses was built on top of a streambank that failed during the recent flood. Future houses will be built farther back, following a fluvial hazard assessment and a local hazard mitigation plan.

#4 Provide Outreach and Training on River Dynamics and River-Smart Practice – A Department of Public Works engineer is being trained in river-smart construction so future roads and bridges will be built to withstand river floods.

#5 Designate, Recognize and Support River-Smart Regional Intermediaries – A technician from a regional planning council is meeting with a farmer as part of developing a flood mitigation program.



riversmart communities

http://extension.umass.edu/riversmart/