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Enforcing Higher Standards for Flood Hazard Mitigation in Vermont

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ENFORCING HIGHER STANDARDS FOR FLOOD HAZARD MITIGATION IN VERMONT

A Thesis Presented

By

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ABSTRACT

ENFORCING A HIGHER STANDARD OF FLOOD HAZARD MITIGATION IN VERMONT

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The state of Vermont faces increasing risk of costly damage from catastrophic flooding events as climate change increases the frequency of heavy rains and cumulative precipitation. In addition to increasing flood inundation risk, extreme precipitation events are leading to high rates damage from fluvial erosion—erosion caused by the force of floodwater and the materials it carries. As in all U.S. states, flood hazard governance in Vermont is shared by multiple levels of government and involves a complex compliance model that relies on local governments to regulate private property owners to achieve community, state, or federal goals.

To encourage municipalities to adopt higher-standard flood regulations, the State government created higher-standard model flood hazard bylaws and has incentivized their adoption through the State Emergency Relief and Assistance Fund program. The higher standards modeled by the State apply no-fill, no-build, and an assortment of additional standards that exceed the Federal Emergency Management Association's National Flood Insurance Program's minimum standards. The State encourages the application of higher standards not only to the federally mapped flood hazard area but also to the State-mapped "river corridor." Though these regulations are enforced through the local flood hazard permitting process, State floodplain

managers are meant to play a substantial advisory role in their regulation. A decade after the first of these flood hazard regulations appeared in Vermont municipalities, little is known about how much encroachment still happens in flood hazard areas and how municipalities have handled permitting projects under these new controls. A better understanding of the local governance of flood hazard regulations can further inform State flood hazard governance.

This study of twelve Vermont towns found in those towns a fairly high degree of conformance to local regulations but a mixed record on compliance with the State's expectations for the permitting process. There was on average a little under one investment per town over a 4.3-year period that was significant enough to, by law, trigger a conditional permit review. Within the study sample, activity in the regulated flood hazard zone conformed to local bylaws at a rate of about 88%. However, only three of the ten projects that triggered conditional review were reviewed at the State level, as is the expectation for new, replacement, or improved structures, and the fact that none of the suspected non-conforming structures received a State-level review (and some missed local review) suggests that receiving full review will increase the rate of individual permit conformance.

Interviews with State officials indicated that the State may be more interested in changing the culture of local flood hazard mitigation than in achieving perfect land use conformance. When local actions that promote access to information and the capacity to regulate are compared with a Town's permitting compliance rate, a slight pattern emerges showing that communities that have flood regulation information available online, town-wide zoning, and a zoning administrator, are more likely to have projects be permitted by the Town and sent to the State for review. Interviews with State-employed flood managers and local floodplain administrators also suggest that additional social factors, such as whether bylaws have community "champions" and who acts as the zoning administrator, may influence the degree of community compliance. Often local authorities rely on their own discretion to regulate activity in the flood hazard area as a way of navigating tensions between regulations and private property rights, representing both a valuable

point of flexibility for compliance and a potential sticking point in the State's effort to facilitate a culture shift.

Flood hazard mitigation regulation in Vermont most closely aligns with a cooperative enforcement model, which relies on long-term relationships and credible threat of enforcement (among other factors) in order to work. Because the findings show that breakdowns in the expected relationship between Town and State government clearly occur, one important approach to achieving a cultural shift would appear to be strengthening State-local relationships. This may involve increasing the State staff-to-community ratio, conducting more community visits and trainings, distributing a flood regulations enforcement manual, strengthening the capacity of regional planning agencies, and/or reducing the barriers to preparing permits for State review. Focusing on long-term relationship-building with a number of community members may help prevent the breakdown in communication that can occur as individual floodplain administrators come and go. A second strategy would continue to support the state-wide housing buyout program to mitigate inequitable outcomes and general resentment over property loss. And because the ERAF incentive program does not have any penalties that incentivize enforcement, a third beneficial approach would involve creating stronger incentives for local enforcement and compliance, such as ERAF criteria that mandates local enforcement actions and improved State-level monitoring of compliance. Yet while there may be room for strengthening flood hazard regulation enforcement, Vermont's innovative regulations and incentives for adoption appear to be translating fairly well into local-level conformance and compliance, and could serve a model for other states.

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ACRONYMS

ANR	Agency of Natural Resources
DEC	Department of Environmental Conservation
ERAF	Emergency Relief Assistance Fund
FEH(A)	Fluvial Erosion Hazard (Area)
FIRM	Flood Insurance Rate Map
GIS	Geographic Information Systems
LOMA	Letter of Map Amendment
NAI	No Adverse Impact
NFIP	National Flood Insurance Program
SFHA	Special Flood Hazard Area

GLOSSARY OF TERMS

Compliance Degree to which the legal process for local flood hazard permitting is followed *(definition specific to this paper);* also, voluntary adherence to official requirements, ofen in support of a widely supported public-interest goal

Conformance Degree to which the legal standard is met in a project that falls under the jurisdiction of local flood hazard bylaws *(definition specific to this paper)*

Constrained The condition in which a river channel is forced to follow a particular course due to physical barriers (e.g. retaining walls, railroads, bridge abutments)

Encroachment Addition of investments in the flood hazard area (see "Investments" below)

Flood/fluvial erosion hazard area The dynamic valley-bottom area that accommodates the dimensions, pattern and profile of a stream channel in its most stable equilibrium condition; generally, six times the bank-full channel width

Flood hazard area The combination of river corridor/flood erosion hazard area and the FEMA-designated Special Flood Hazard Area *(definition specific to this paper)*

Floodway (a.k.a. "regulatory floodway") The channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height; FEMA-designated

Fluvial geomorphic assessment Scientific evaluation of the physical condition of a river system based on geomorphic features, flood frequency analysis, water and sediment transport processes, and levels of stream degradation

Higher-standards flood hazard bylaws Municipal bylaws that contain, in full or in part, State-defined No Adverse Impact Standards, additional restrictive standards, and the flood erosion hazard or river corridor jurisdictional layer *(definition specific to this paper)*

Incised The condition in which a river channel is experiencing bed-level lowering

Inundation Immersion in water; does not characterize water movement (velocity) or force applied as a result of water velocity

Investments Assets in the flood hazard area that reduce the space available to the river and floodwaters and/or that contribute to likelihood that a property owner or public authorities will manipulate the river channel to protect those assets, i.e., structures, parking lots, cut and fill projects, and renewable energy installations

Meander belt Width containing the widest lateral extent of river/stream meanders

River corridor Flood erosion hazard area plus 50' buffer on each side

Special Flood Hazard Area Defined by the Federal Emergency Management Agency for the National Flood Insurance Program as having a one-percent change of being inundated by flood waters in any given year (also known as the 100-year floodplain)

CHAPTER 1

INTRODUCTION

Vermont policy makers, advocates, regional planning agencies, and town boards are doing important work at the nexus of natural resource protection and hazard mitigation by evolving a new zoning tool aimed at keeping people and infrastructure out of the way of complex, climate- and climate-change-influenced river and stream[1] dynamics. Prior to the late 1990s, flood hazard management in Vermont primarily focused on areas within the mapped inundation zone and on regulating to the minimum federal standards for the National Flood Insurance Program (NFIP). After a series of damaging flood events in the 1990s, the state became significantly more aware of the risks associated with fluvial erosion—a process caused by the erosive force of moving floodwaters and the additional force of materials carried by those waters (Kline and Cahoon 2010). These events shifted the public conversation from one simply about inundation, to inundation and fluvial erosion risk. Concurrently, floodplain management professionals' recognition—in Vermont and nationwide—of the wholesale failure of federal flood management policy to adequately protect people and property from both erosion and inundation flood hazards has precipitated a cultural shift toward designing regulations that prevent adverse impact to riverside properties (Association of State Floodplain Managers 2008). That cultural shift is apparent in local adoption of a menu of improved standards: erosion hazard protection in the river corridor, flood inundation standards higher than the minimum NFIP standards, and additional regulations that provide added protection and ensure *conformance*, or the degree to which the legal standard is met by a project.

The push over the last three decades to integrate better flood hazard management has occurred at both the state and local level. At the state level, organizational restructuring and new

[1] For simplicity sake, I refer only to rivers in the remainder of this paper, though the regulations and natural processes discussed apply equally to streams.

policies and programs that focus on nonstructural river management stand in marked contrast to the management strategies of the early 1990s. From this shift emerged the Vermont's Rivers Program, the Department of Environmental Conservation (DEC) program within the Agency of Natural Resources (ANR) responsible for "protecting and restoring natural river and floodplain processes to enhance water quality, ecological health, and flood resilience ("Rivers Program" n.d.). The Rivers Program operates its flood resilience programs with the intention of bringing about a broad cultural shift in how communities understand river function and how they view land use in floodplains and river corridors.

As the state's flood management paradigm has evolved in response to damaging floods, the role of local municipalities has become more important. Leaders in the State's Rivers Program contend that "towns have to support the variety of ways in which rivers function" (Kline and Evans 2019). In addition to hazard mitigation planning, conservation easements, and other mitigation strategies, municipalities are starting to use regulations—both flood hazard zoning attachments and standalone bylaws—to preclude investments in riverine areas.[2] Limiting new investment in the flood hazard zones both avoids increasing the number of structures that are vulnerable to flood damage and helps preserve healthy river function. The majority of the flood hazard area in the state falls under local jurisdiction and thus it is on town governments to implement what the State regards as best practices for flood hazard mitigation. Assuming higher-standard flood regulations when implemented do indeed produce the improved outcomes, the effectiveness of local regulations hinges on the degree to which structures in the flood hazard area *conform* to, or fully meet the standard of, the local regulations, as interpreted and enforced by the local authority. However, the State has not fully left interpretation up to the local authority: in the case of most types of investment, Towns are required to submit permit applications to the State's

[2] The term investment, rather than development, reflects a property owner's predisposition to alter a river channel to protect or "improve" the investment (see "Increasing Flood Hazard Risk in Vermont").

Rivers Program regional floodplain managers for technical review. Assuming that the State's review increases the rate of local conformance, the degree of *compliance* of local authorities with the legal process for local permitting (specifically state review) is also important to the effectiveness of flood hazard regulation adoption.

As of 2019, nearly one-third of Vermont towns had adopted some form of higher-standard flood hazard regulations; many of these towns, though not all, also applied these regulations to the river corridor. The Rivers Program and multiple non-governmental organizations involved in resource protection and hazard mitigation are themselves interested in understanding the adoption, use, enforcement, and effectiveness of flood hazard bylaws to inform policy advocacy related to state government size and structure, incentive programs, Vermont's land use and development law (Act 250), and more.[3] To be informed, stakeholders need to better understand the chain of influence governing the built environment in flood hazard areas, including how local planners and planning boards apply and interpret protective land use regulations.

This study looks at how the presence of higher-standards flood hazard bylaws, implemented under Vermont's land use planning statute (24 V.S.A. §4424), influence the occurrence and permitting of investment in the regulated flood hazard area. The twelve Vermont towns that had "interim" river corridors (flood hazard zoning bylaws with no-cut/fill/build/improvement standards) selected for this study's multi-step case study review provide a snapshot of the frequency, types of, and conditions under which encroachment occurred in the mid-2010s. Using local bylaws, geographic information system (GIS) layers, and imagery to conduct visual analysis of land use change, the study examines the frequency and nature of investments (defined as structures, parking lots, cut and fill projects, and renewable energy

[3] I make this statement based on my exploratory interviews with stakeholders for this thesis and the existence of two small studies of Vermont river corridor bylaws conducted in the last few years (Stepenuck 2016; Halladay 2018)

installations) occurring in the regulated and unregulated flood hazard area, the frequency and nature of investments that should have triggered local review to determine rate of investment, and zoning conformance. Activity in regulated flood hazard areas that should have triggered local discretionary review were further reviewed for local compliance with the legal process for permitting in the flood hazard area.

While most of the incidents identified in the visual analysis were permitted by right, a number of incidents should have triggered discretionary/conditional review at the local level and, consequently, technical review at the state level. Together, this data and contextual information collected from state and town officials provide a picture of how higher-standard flood hazard regulations are applied in flood hazard areas. The case studies reveal that many of the themes that dominate the discourse on land use regulation for hazard mitigation—the tension between private rights and public good, the challenges of multi-level flood hazard governance, and the complex dynamics affecting conformance and enforcement of flood hazard regulations—hold true in the Vermont context and are important lenses through which to think about conformance, compliance, and possible changes in flood hazard governance.

Regulating the river corridor and applying higher standards to the entire flood hazard area are significant innovations in natural resource protection and hazard mitigation management, ones that takes a broader view of the river in hazard planning. This new management paradigm provides more room for the river, preserving the space a river needs to function as a natural system and protecting nearby human investments from the river's growing reach and erosive power. As one of only two states regulating river corridors (Association of State Floodplain Managers 2016), Vermont is a model for the country in fluvial erosion hazard mitigation planning. Based on review of the literature, it also appears to be one of the only states incentivizing No Adverse Impact flood hazard mitigation approaches. It is thus critical to other states looking to Vermont for leadership, and not just Vermont stakeholders, to understand whether higher-standard flood erosion and inundation policies work at the community level as

intended. This research will help understand how these zoning bylaws are being applied locally, in order for Vermont to continue advancing the art and science of planning in the race against climate change.

CHAPTER 2

BACKGROUND

Increasing Flood Hazard Risk in Vermont

The state of Vermont experienced a Federal Emergency Management Agency (FEMA)-declared Severe Storms and Flooding major disaster eight of the nine years between 2011 and 2019. In the worst of those years, 2011, the devastation wrought by Tropical Storm Irene was preceded by multiple damaging spring and summer storm and flood events. Observation of increased rates of heavy precipitation events throughout the last century links anthropogenic climate change to increasing rates of urban and fluvial flooding. Huang et al. (2017) documented a 6.8% increase in total precipitation in the northeastern United States between 1901 and 2014, and a 41% increase in extreme precipitation events over the same period. The same study found a dramatic increase in the yearly occurrence of extreme precipitation events starting in 1996, indicating that instead of a gradual, linear, upward trend of intense rain events, the rate of increase in precipitation events may be accelerating.

When Tropical Storm Irene reached Vermont in late August 2011, up to 11 inches of rain fell in parts of the state over a 24-hour period, with the greatest flooding occurring along the eastern slopes and foothills of the Green Mountains. After the rains ceased, 34 bridges and over 500 miles of roads were damaged, many structures were wiped out—including a state government building complex in Waterbury—and six people had lost their lives (Hewitt 2016).

Irene concluded five months of damaging extreme events in Vermont that year, including federally declared flood disasters in April, May, and June. The cumulative precipitation in 2011 resulted in wetter baseline conditions and, in the case of Irene, increased erosion of river and stream channels (Yellen et al. 2016). The damage Tropical Storm Irene caused was, thus, the result of high cumulative precipitation resulting from the intensity and frequency of precipitation associated with climate change. As of June 2013, FEMA had spent $260 million on recovery and

hazard mitigation from the 2011 rain events (Cohen et al. 2013) [4] and the agency continues to fund the purchase of homes as part of the state's housing buyout program ("FEMA/HUD Buyout Coordination" n.d.).[5] The risk of flood damage was also not new to Vermont: in 2011, Kline and Dolan (2008) report that prior to 2008, flood losses, damages, risk to public safety, and recovery cost Vermonters $14 million in damages yearly.

A combination of geographic features and processes, historic settlement patterns, and federal flood policy makes Vermont vulnerable to severe flash flooding in its river systems. Vermont is a mountainous area experiencing ongoing post-glacial rebound, meaning that the slope of landforms continues to steepen and the majority of its streams and rivers are highly dynamic. [6] Abenaki, Mahican, and Penacook Indians hunted and occupied Vermont for 10,000 years prior to European settlement. Throughout the 1700s, Europeans and European-Americans settled the state's hilltops with farms. In the 1800s, a period of mill and settlement building produced relatively compact, linear villages on the flood terraces along rivers. Twentieth-century earth-moving and building engineering has since allowed more growth on steep-sloped terrain, but the legacy of valley and floodplain settlement remains.

Vermont's unique topography and settlement patterns expose its residents to consequences beyond *inundation*, or immersion, from flood water. As early as the 1990s, Vermont floodplain managers and legislators recognized that the majority of flood damage costs

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[4] Over seventy percent of disaster recovery funds were channeled from FEMA to towns and homeowners via FEMA's Individuals and Households Program, public assistance to towns, the Hazard Mitigation Grant Program, and Nation Flood Insurance Program payments. Twenty-eight percent went to state public assistance, and the remaining one percent to other organizations (Cohen et al. 2013). The state, non-profits, and philanthropic organizations also contributed funds to rebuilding.

[5] Ongoing buyout efforts on the part of the state are funded by FEMA's Hazard Mitigation Program, the Department of Housing and Urban Development's (HUD) Community Development Block Grant (CDBG) Disaster Recovery Program, and Vermont's Housing and Conservation Fund (Geiger and Oates 2019).

[6] As of the early 2000s, prominent environmental planning literature did not identify fluvial erosion as a flood risk hazard (see for example, Daniels and Daniels (2003)).

of previous decades derived from fluvial erosion, rather than fluvial inundation, along Vermont's 23,000 miles of river systems (Kline and Cahoon 2010). This awareness grew alongside similar recognition of fluvial erosion at the federal level and among state floodplain professionals (Federal Emergency Management Agency 1999; Association of State Floodplain Managers 2016).

Rivers that can adjust their channel geometry (width, depth, and slope) in response to the flow of water, sediment, and debris without increasing (aggradation) or decreasing (degradation) their channel bed are considered to be in a relatively stable state known as dynamic equilibrium (Leopold 1994). A healthy river will make channel adjustments—change the shape of its meander—to maintain dynamic equilibrium. Maintaining this stable state requires the river to be able to adjust laterally into the land surrounding it, an area called the *corridor* (Kline and Cahoon 2010).

Land use change in the corridor and manipulation of the channel can negatively impact natural river function. These activities limit the river's access to its historical floodplain to discharge energy and sediment and/or shorten the river channel (thereby increasing its slope and velocity). C*onstrained* river channels—channels forced to follow a particular course due to physical barriers (e.g. retaining walls, railroads, bridge abutments)--become increasingly *incised*, or the river is experiencing bed-level lowering (Wang, Lee, and Melching 2015). Incision is condition in which the river channel has eroded downward (deeper) to the point where in a normal high-volume event, the river's banks are too high to allow the river to access its floodplain to disperse water and sediment energy. Human stream-channel alteration such as dredging, the construction of berms, damming, and channelization on Vermont rivers has severely exacerbated channel erosion and deposition processes (Kline and Cahoon 2010). As of 2010, nearly three-quarters of mapped Vermont rivers and streams were incised (Kline and Cahoon 2010). Constrained and incised rivers are more likely to experience *fluvial erosion*, the erosion and undercutting of riverbanks, because there is an excess of energy (water) and material

(sediments) in the channel scouring outside bends of the channel meander. When combined with extreme climate events, rivers prone to excessive fluvial erosion can put nearby agriculture, transportation, waste management, housing, and various other infrastructure at risk.

Federal floodplain mapping science does not consider the types of channel evolution processes seen in Vermont and much of the federal mapping occurred after the majority of Vermont channels were incised and disconnected from their floodplain. FEMA FIRMS thus often represent floodplains as more narrow then they likely were prior to human alteration, which has allowed development to occur in areas at high risk of erosion hazards (Kline and Cahoon 2010).[7] Unlike flood damage from inundation, fluvial erosion can 1) occur on lands outside the FEMA flood insurance rate map's (FIRM) 100-year floodplain, 2) occur during flows that are much smaller than the 100-year events, and 3) can result in loss of land underneath a structure, preventing any kind of rebuilding (Association of State Floodplain Managers 2016). These added hazards can make damage caused by fluvial erosion significantly more costly than inundation damage.

To better account for fluvial erosion, Vermont devised a protocol for mapping erosion hazard risk. Vermont calls the river's meander corridor the *fluvial erosion hazard area* (FEHA) and defines it as the "dynamic valley-bottom area that accommodates the dimensions, pattern and profile of a stream channel in its most stable equilibrium condition" (Kline and Cahoon 2010, 231).[8] The FEHA is determined using an official State protocol for *fluvial geomorphic assessment* that is based on Rosgen and Silvey's (1996) classification and assessment techniques. Fluvial

[7] It is worth noting also that with climate change, the recurrence interval for large flood events is decreasing, which is to say that storms either get bigger, or the same-sized storm comes more frequently, making FEMA FIRMs—which represent historic data and not climate change-sensitive projections—less accurate and less inclusive over time.

[8] Other scientists and floodplain managers have offered different, sometimes more nuanced definitions or assessment tools for the term "river corridor," and other terms have been used to describe a similar river-process area as that encompassed by Vermont's use of the term river corridor (Warner, Gartner, and Hatch 2018).

geomorphology is the study of how geologic features, water and sediment transport processes, and levels of stream degradation alter the physical shapes of rivers and bordering landforms (Vogel et al. 2016). To determine the FEHA, the State looks at the present or historic maximum *meander belt* width, or lateral extent of river/stream meanders, of a river presently in dynamic equilibrium; where rivers have been straightened, the meander belt is estimated at approximately six times the bank-full channel width (see Figure 1) (Kline and Cahoon 2010). The addition of a 50-foot buffer—for margin of error, water filtration, and riparian protection, among other reasons—to the FEHA produces the full protection area, an area termed the *river corridor* (Vermont Agency of Natural Resources 2017).

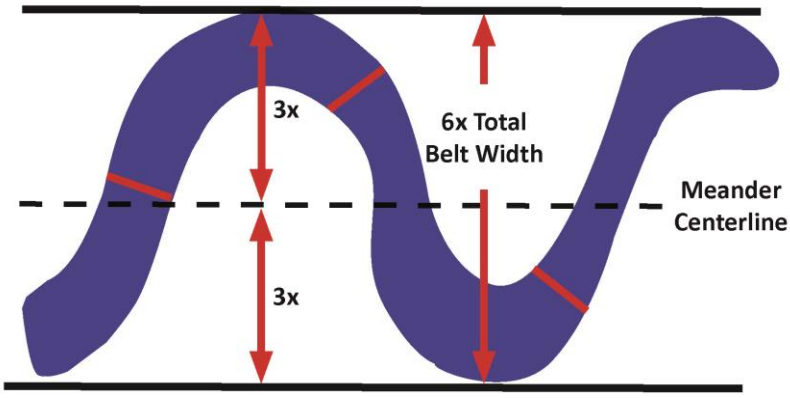

Figure 1. Meander Belt (based on imagery from floodready.vermont.gov)

Recognizing the importance of identifying areas of fluvial erosion risk, the Rivers Program, a program within the DEC, has mapped the extents of river corridors in watersheds greater than two square miles for the entire state. Most of the mapped river corridor overlaps the FEMA Special Flood Hazard Areas (SFHA), the area defined as having a one-percent change of being inundated by flood waters in any given year (also known as the 100-year floodplain). But the river corridor will extend beyond the bounds of the SFHA in places, such as elevated erodible banks, that are at risk for fluvial erosion (see Figure 2). In the early years of the State's stream geomorphic assessment program, FEHA maps were produced primarily for regulating projects

that fell under the purview of Act 250 (Vermont's statewide land use and development law for public and large-scale development projects) or upon request by a municipality, so they were not completed in every town nor for every reach within a town. In this period, only the FEHA was delineated, not the full river corridor. The transition to mapping river corridors—the only maps now available to towns on the Vermont Flood Ready Atlas—took place around 2012, spurred by legislative action taken in response to Tropical Storm Irene. Currently, the State has mapped 100% of river and stream corridors with over a 2-square-mile watershed ("River Corridors - Frequently Asked Questions" n.d.). The mapped river corridor and FEHA delineate the jurisdictional layer that can be folded into existing floodplain regulations. For the purposes of this study, I refer to the combined of river corridor/FEHA and the FEMA-designated SFHA as the *flood hazard area*.

Figure 2. River Corridor vs. Floodplain (image credit: Vermont Agency of Natural Resources)

Another important dimension of Vermont's approach to assessing flood risk is its orientation toward the concepts of *investment* as the primary driver of increased flood hazard. Rather than focusing on development—which doesn't usually include cut and fill projects—or on changes to permeability—which correlates only with floodwater displacement—the State is concerned with the creation of assets in the flood hazard area that could lead to manipulation of the stream channel (Kline and Evans 2019). Property owners who see inundation or erosion as a threat to their investments are more likely to channelize the stream by straightening or armoring its banks, activities that may raise the risk of damages upstream (as water backs up behind a pinch point), at that location, or downstream (due to increased velocity). This research therefore focuses on investments such as structures, parking lots, cut and fill projects, and renewable energy installations, and not on broader land use changes such as forest cutting or land conversion. To align with the State's semantic approach, this paper will refer to assets in the flood hazard area as investments or projects, rather than development, and the addition of investments as investment or *encroachment*. The term development may be used when discussing FEMA-designated flood hazard areas.

Adopting the No Adverse Impact Standard

Around the same time that Vermont was beginning to map FEHAs and applying them to its regulatory and advisory efforts, it was also integrating "No Adverse Impact" (NAI) floodplain management. Originally proposed by Larson and Placencia (2001), the NAI approach aims to shift the focus in floodplain management from techniques and standards for developing in the floodplain to mitigating the adverse impacts of flood-prone land use. In 2008 the Association of State Floodplain Managers' published a white paper promoting this do-no-harm principle in which it takes the position that the conventional local approach to flood hazard mitigation—adoption of minimum NFIP standards in exchange for insurance (which indirectly subsidizes

floodplain development)—does not adequately protect communities from floods. The Association outlines the inadequacies and impacts of federal minimum standards:

> Current national standards for floodplain management allow development activity to divert flood waters onto other properties; to reduce the size of natural channel and overbank conveyance areas; to fill essential valley storage space; and to alter water velocities—all with little or no regard for how these changes affect other people and property in the floodplain or elsewhere in the watershed. The net result is that our own actions are intensifying the potential for flood damage. The current course is one that will result in continually rising costs over time, is not equitable to those whose property is affected, has been shown to be economically and environmentally unsustainable, and is a pattern of conduct generally not supported by the courts. (1)

The association instead champions management in which the "action of one property owner is not allowed to adversely affect the rights of other property owners" (2).

The State of Vermont integrates this principal into its floodplain management in the form of its No Adverse Impact Standards. These standards can be summarized as 1) in the river corridor: no new fill, substantial excavations, structures, or improvements;[9] 2) in the FEMA-designated *floodway*: no new development (unless it is certified by an engineer to have no impact or by FEMA as being out of the floodway); and 3) in the SFHA: any new development will also provide compensatory storage to offset displaced floodwater storage. Items 2) and 3) in this list represent standards that are higher than basic FEMA minimum standards and are common, though not universal, local standards (for a full list of differences between the NFIP minimum standards and the Vermont model bylaw higher standards, see Appendix A). Vermont identifies these standards as an NAI approach, though this may not be a universal interpretation. Together, NAI standards, additional higher standards promoted in the model bylaws for municipalities (see A Comprehensive and Evolving Approach to Flood Hazard Mitigation subsection), and the integration of the FEHA and/or river corridor make up what I will refer to in this paper as *higher-standards* when describing the bylaws studied in this research.

[9] The intent behind "no improvements" is to have no substantial improvements to primary structures (Ned Swanberg personal communication, April 2020).

A Comprehensive and Evolving Approach to Flood Hazard Mitigation

The Rivers Program's resource management and hazard mitigation strategies have evolved over the past two decades from an emphasis on active, expensive natural channel design restoration techniques to a mix of passive and active river management techniques and inter-agency collaborations designed to promote, not impose, stable channel equilibrium. Prior to 1999, multiple state programs managed Vermont's rivers systems, all favoring engineering solutions to stream instability and riparian restoration projects popular at the time. In the 1990s, after a series of costly floods, the Act 137 report commissioned by the state legislature found that NFIP damage claims were more likely to be a response to fluvial erosion than inundation, suggesting that intensive river management and flood mapping practiced at the time in fact had destructive consequences (Kline and Cahoon 2010). The passage of Act 137 in 1998 initiated the establishment of Vermont's Agency of Natural Resource's Fluvial Erosion Hazard Program (now the River Corridor and Floodplain Protection Program, a program run by the River's Program), whose principal objective was to "promote long-term river stability to provide both protection from flood damage and a healthy riverine function" (Vermont Department of Environmental Conservation 2016). This mandate to place river corridor science at the center of river management also precipitated a change in the governance structure of river management. In the late 1990s, the Stream Alteration, Buffer Restoration, and NFIP programs merged into what is now called the Vermont Rivers Program.

Between 2010 and 2014 the State passed a set of statutory changes establishing policy and directives to the Rivers Program to "map flood hazard areas and river corridors […], promote their protection in municipalities [sic] planning and zoning, establish state protective procedures, and regulate activities exempt from municipal regulation" (Vermont Department of Environmental Conservation 2016, 15). One of these acts, Act 110 (2010), established ANR's river corridor policy, defining a river corridor as a means to "reduce fluvial erosion hazards" and "sustain the social, economic, and ecological sustainability of Vermont communities," and

directing the State to manage rivers "towards dynamic equilibrium" (Kline n.d., 1). Act 138 (2012), enabled state river-area regulations to be more restrictive than NFIP standards. Act 16 (2013) introduced the requirement that municipal and regional plans must include consideration of river corridor and flood hazard area protection and Act 107 (2014) explicitly called for the protection of river corridors in state policy. Taken together, these Acts represent an effort on the part of state leadership to mainstream science-based river management into the state's hazard mitigation work at all levels of government.

These directives greatly accelerated ANR's, specifically the Rivers Program's, work to promote a comprehensive suite of river management and hazard mitigation tools that includes select river restoration projects, an easement program, publicly available river corridor maps, alignment with the states' transit authority on road and road infrastructure standards, procedural rules for evaluation of projects that fall under the State zoning regulation (Act 250), incentives for local planning and regulation, and model land use regulations—the latter of two of these tools being the primary focus of this research. A number of major policy developments were needed to enable these tools. First, the Rivers Program completed Phases 1 & 2 of its stream geomorphic assessment of rivers and streams statewide, making river corridor data available to all Vermont municipalities (pursuant to 10 V.S.A. §§1422, 1427, 1428). Second, the State adopted in 2014 the ANR Flood Hazard Area and River Corridor (FHARC) Rule (pursuant to 10 V.S.A. §§751, 752, 753). The FHARC rule regulates land use in areas exempt from municipal regulation, such as state-owned institutions and facilities, certain agricultural practices, and power-generation, transmission, and telecommunication facilities, to ensure that projects are "safe and accomplished in a manner that is consistent with the public health, safety, and welfare, and does not impair stream equilibrium, floodplain services, or the river corridor" (Vermont Agency of Natural Resources 2014, 3). This rule officially introduces the No Adverse Impact Standards. Third, in 2015, the State also adopted the DEC Vermont Flood Hazard Area and River Corridor Procedure, later revised in 2017. The FHARC Procedure describes how the DEC applies the NAI standard to

the State's technical assistance and regulatory recommendations, to Act 250, and to other regulatory agencies. The Procedure also includes a list of practices to promote stream and floodplain equilibrium. Fourth, and most importantly to this project, the State land use planning statute (24 VSA §4424) enables municipalities to adopt bylaws to control development in hazard areas so as to prevent or minimize the loss of life and property. Finally, the FEMA-approved State Hazard Mitigation Plan (Vermont Emergency Management 2018) more fully integrated the State's goal of reducing flooding and fluvial erosion hazards, holding river corridor protection as a high priority in hazard mitigation project prioritization.

To encourage local protection of the river corridor, in 2009 the Rivers Program released multiple FEHA model bylaws that they recommended for towns with FEMA FIRMs (Vermont Agency of Natural Resources 2009). These model regulations incorporated the important innovations to flood hazard mitigation recognized by the State: the No Adverse Impact Standard, the application of that higher-standard to the river corridor/FEHA in addition to the SFHA, and a few additional higher standards.[10] Combined, these elements represent the State's effort to close the gap between the level of protection achieved by the NFIP—the inadequacies and impacts of which were well outlined by the Association of State Floodplain Managers—and what they see as necessary to effectively mitigate hazard vulnerability. In 2018 the Rivers Program released a new version of the higher-standard model bylaws which brought the language for municipal river corridor protection into alignment with the 2014 FHARC Rule and 2017 FHARC procedure for public projects (Vermont Agency of Natural Resources 2018).[11] Although regulation of the river

[10] The additional standards include prohibiting building of critical facilities, raising the height of the first floor over base flood elevation, tracking substantial improvements over a 3-year period to ensure that flood regulations are triggered by cumulative reinvestment, requiring a certificate of occupancy to ensure that projects were built as permitted, and requiring access to the primary structure by dry land outside the flood hazard area.

[11] The updated bylaws allow for more flexibility in downtown areas where infill is an appropriate growth strategy. They allow infill that "shadows" existing buildings, in which structures are no closer to the

corridor and SFHA falls to towns, the Rivers Program was designed to maintain a significant presence in local regulation. Under the Municipal and County Governments state statute (24 V.S.A. §4424 (a)(2)(D)), municipalities are required to submit permit applications for new construction or substantial improvement in the flood hazard area or river corridor to the Department of Conservation for review.

The State promotes the adoption of higher-standard flood hazard bylaws through its flagship pre-disaster mitigation incentive program, the Emergency Relief and Assistance Fund (ERAF). Following the criteria rules for ERAF established in 2012 under Act 138, the state's cost-share percentage for emergency relief and assistance increases from 7.5% to 12.5% to 17.5% as a municipality adopts a suite of community-level mitigation actions, adoption of a river corridor zoning bylaw being mandatory for reaching 17.5% cost share (Christin and Kline 2017).[12] Early on in the program, the State offered more flexibility in how higher-standard flood hazard bylaws could be applied to qualify for full matching funds with ERAF, allowing three partial applications: 1) application of the higher standard to some or all FEHAs in addition to the SFHA, 2) application of the higher standard to the SFHA but not the FEHA/river corridor, or 3) some combination. This era of flexible adoption created a hodgepodge of bylaw types and over

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channel than the adjacent existing primary structures and do not increase the displacement of water. This change makes the bylaws compatible with the State's goal of fostering smart growth, a planning principle that promotes compact, walkable urban cores. Smart growth logic challenges nonstructural flood hazard mitigation theory (outlined in the Literature Review section), suggesting that it may make sense to armor flood-prone areas where density and infill benefit the economic and social vibrancy of a downtown.

[12] To receive a state match of 12.5 percent, municipalities must:
1) Adopt a local emergency management plan to improve disaster response when flooding strike
2) Coordinate local agencies' flood protection efforts through a hazard mitigation plan
3) Meet minimum criteria for participating in NFIP
4) Adopt the Vermont Agency of Transportation's most recent standards for resilient roads and bridges.

To receive a state match of 17.5% municipalities must take one of these two additional actions:
1) Adopt a river corridor protection bylaw that meets or exceeds state regulations and guidelines
2) Participate in FEMA's Community Rating System and prohibit new structures in special flood hazard areas ("Emergency Relief and Assistance Fund" n.d.).

fifty municipal bylaws that did not apply all of the minimum regulations outlined in the 2014 FHARC procedure. For the purposes of ERAF qualification, these bylaws are referred to as "interim" bylaws. Interestingly, in some cases, interim bylaws are stricter than the "updated" bylaws because they do not allow for infill and have stricter standards for other uses in flood hazard area.

Recently the State modified the qualifying criteria for ERAF so that a municipality must now meet or exceed the standards outlined in the updated 2018 model bylaws (including full application of river corridor zoning) in order to qualify for the maximum 17.5% cost share.[13] This means that towns with "interim" bylaws will soon no longer qualify for the full amount of matching funds under ERAF. As of 2019, over 90 towns—nearly one-third of the state—had adopted some form of higher-standard flood hazard zoning, but the rate of adoption has slowed. and most towns have only "interim" bylaws. The new ERAF requirements may precipitate further adoption of higher standards, but this has yet to be seen.

Improved understanding of healthy river function and flood hazard risk in a changing climate precipitated a paradigm shift in how Vermonters manage their rivers over the last three decades. Municipal land use controls that consider fluvial erosion risk and that have integrated higher standards than the NFIP minimum are an essential part of the state's progressive flood hazard migration strategy both because they help prevent Vermonters from increasing their vulnerability and because they educate Vermonters about flood hazard risks and science-based river management.[14] Now that the higher-standard flood hazard bylaws have been adopted in

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[13] The new criteria require that the municipality: apply the bylaw to all mapped river corridors, apply a 50' setback to streams with a watershed less than two square miles, and adopt minimum regulatory requirements consistent with the 2014 FHARC Procedure.

[14] Godschalk et al. (1999) argue that in the context of natural hazards mitigation regulations, the conflict between private property rights and public harm/good should resolve themselves through sound scientific knowledge. However, the inaccuracy of FEMA FIRMs is overlooked by property owners and local authorities. The State of Vermont's geomorphic assessment protocol may also be seen by some as arbitrary; others have proposed more nuanced approaches to mapping the river corridor. This puts into question whether there is such a thing as a fully science-based approach.

around one-third of the state's municipalities, their impact on municipal practices and on the land should be noticeable.

CHAPTER 3

SIGNIFICANCE OF RESEARCH AND RESEARCH QUESTION

Significance of Research

While many other states and many communities within Vermont remain cautious about using land use regulation to promote natural resource protection, the State of Vermont has leaned into regulation as a tool for hazard mitigation by raising the standards for flood hazard areas generally and by mainstreaming river corridor protection into all of their hazard mitigation work. A few other states have made similar efforts: Arizona, Colorado, Indiana, Massachusetts, New Hampshire, and Oregon promote the mapping and protection of fluvial geomorphic river corridors. But as of 2016, only Washington state government may be involved in river corridor land use regulation (Association of State Floodplain Managers 2016). Massachusetts created a task force to study river corridor mapping techniques (Warner, Gartner, and Hatch 2018), tested a river corridor mapping procedure on the North River in Franklin County (Field 2018), and the Franklin County Regional Governments (FRCOG) recently released model river corridor bylaws as part of a River Corridor Management Toolkit (MacPhee 2019), but these Massachusetts river corridor bylaws are neither mandatory nor incentivized nor overseen at the state level, and it is too early in the evolution of this effort to compare impacts.[15] The fact that the application of river corridor zoning still remains in its early stages across the country, and even in Vermont the actual impact of higher-standard zoning on the built environment has not yet been very well studied, demonstrates the need for research that can provide real insight into the effectiveness of higher

[15] It should be noted that the 200-foot buffer (Riverfront Area), regulated as a no-remove, fill, dredge, or alter area by the Massachusetts River Protection Act, is sufficiently large as to encompass most of the VT-defined river corridor in many areas and the protection has been in place much longer, so any absence of effective river corridor regulation does not necessarily equate to the absence of effective river corridor protection in Massachusetts, and possibly other states.

standards and the inclusion of the river corridor zoning vis-a-vis a state's and its communities' hazard mitigation goals.

Most bylaws from the twelve towns sampled for this study contain boilerplate language from the 2009 model bylaws focused on avoiding flooding's negative impacts, preserving floodplain and river corridor services, and compliance with state and federal requirements for funding.[16] Interestingly, most of the communities looked at in this study adopted higher-standard bylaws prior to 2012 when the initial ERAF criteria was established. The sample towns that adopted bylaws in 2012 may have been responding to the ERAF criteria, but the nine towns in the sample that adopted higher-standard bylaws around 2010 were likely motivated by some combination of NFIP-related deadlines, community priorities, the prevalence (and perhaps newness) of fluvial geomorphic assessments and presentations by the State at the time, and the engagement of many groups (watershed coalitions, regional planners, the Vermont League of Cities and Towns, and others) (Ned Swanberg personal communication, May 2020).

The leaders of the Rivers Program, which facilitates and supports community-level flood hazard regulation, does not purport to be working toward any specific target for reducing new investment in the river corridor. Instead, they speak about a desire to change Vermonters' land use expectations over time, growing the degree of caution and inclination toward assessment around investing in the flood hazard area on the part of local governments and individuals (Kline

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[16] Exact language of the 2009 model flood hazard regulations purpose statement:

A. Implement the goals, policies, and recommendations in the current municipal plan;

B. Avoid and minimize the loss of life and property, the disruption of commerce, the impairment of the tax base, and the extraordinary public expenditures and demands on public services that result from flooding related inundation and erosion;

C. Ensure that the selection, design, creation, and use of development in hazard areas is reasonably safe and accomplished in a manner that is consistent with public wellbeing, does not impair stream equilibrium, flood plain services, or the stream corridor;

D. Manage all flood hazard areas designated pursuant to 10 V.S.A. Chapter 32 § 753, the municipal hazard mitigation plan; and make the Town/City/Village of _____, its citizens, and businesses eligible for federal flood insurance, federal disaster recovery funds, and hazard mitigation funds as may be available. (Agency of Natural Resources 2009)

and Evans 2019). This cultural shift, would manifest first as an aversion to projects in the river corridor on the part of consultants and developers similar to their aversion to Class 2 wetlands, where activities not exempt or considered an "allowed use" requires a permit ("Jurisdictional Wetlands" n.d.). Under this paradigm, one could reasonably hope that simply the knowledge that an area is in the river corridor would function as a deterrent, even if an investment could technically be permitted. This culture of caution would rely on the Town providing adequate information and technical expertise—basic elements of local flood hazard governance that Rivers Program employees have expressed concern about (Ned Swanberg phone interview, April 2020; Sacha Peeler personal communication, May 2020). Second, the State hopes that landowners, developers, and local governments become diligent in their obligation to request permit review. This cultural shift would manifest as a transformation in how property owners/developers, local authorities, and the State perceive and relate one another.

The Rivers Program currently works toward their goal that Vermont undergo a cultural shift at community level by promoting bylaw adoption, expanding public awareness, and supporting municipalities in interpreting and enforcing the regulations. As State officials, policy makers, and advocates prepare for revision to ERAF and Act 250 and continue to look for leverage points in hazard mitigation planning generally, interviews with multiple stakeholders (see Methods Goals and Objectives subsection) indicated that a better understanding of how higher-standard bylaws are working at the local level should inform what the State's role should be in promoting good regulation of flood hazards. They are asking, What are the barriers to adopting river corridor bylaws? Are all projects coming under review by the Town and by the State? How successfully are towns enforcing the bylaws? Ninety percent of Vermont towns participate in the NFIP, which limits floodplain development, but the majority of those towns don't have the capacity to manage the application of these regulations, and flood erosion hazard regulations add another layer of difficulty to this (Kline and Evans 2019). If regulation at the local level is not working, there may be an argument for shifting responsibility for the regulation

of the river corridor to the state level, by, for example, expanding Act 250 to regulate more aspects of the river corridor.

The nature and impact of Vermont's river corridor policies has been studied from the angles of mapping protocol, barriers to bylaw adoption, and bylaw adoption on river corridor development. Warner, Gartner, and Hatch (2018) have compared Vermont's protocol for developing state-level geomorphic assessment programs to that of other states. Stepenuck (2016) surveyed thirty regional planners, elected officials, and ANR employees about municipal adoption of river corridor bylaws and found that towns do not adopt river corridor bylaws due to the following barriers, in order of greatest importance: respect for private property rights, lack of technical expertise in town government, community members oppose regulation,[17] lack of staff time, lack of understanding of reasons to protect, uncertainty about alternatives to land development, lack of familiarity with the river corridor, concern for tax base, and no mention of corridor protection in the municipal plan.

Halladay (unpublished manuscript, 2018) asked a parallel question in interviews with fifteen regional planners and hazard mitigation stakeholders: Why do [Vermont] communities develop their mapped river corridor? Over 50% of respondents identified lack of knowledge and respect for private property as likely reasons, with a smaller percentage identifying economic pressure and inadequate enforcement as likely reasons. Interestingly, these responses reinforce Stepenuck's (2016) finding that concern for government overreach into private property rights limits communities' engagement with river corridor bylaws. Halladay does not define "lack of knowledge"—it's unclear whether this is lack of knowledge (technical expertise) on the part of town government, or lack of awareness among the public—so it's difficult to compare his finding to Stepenuck's on the importance of technical expertise.

[17]Though scoring high, "lack of technical expertise in town government" and "community members oppose regulation" did not show a significant difference from "wanting to respect private property rights" based on t-tests ($p<0.05$).

Halladay (unpublished manuscript, 2018) also looked at whether the presence of (mostly interim) river corridor bylaws impacted the amount of investment in the river corridor compared with towns without. This study of 30 Vermont towns found that over the five-year period from 2011 to 2016, towns with interim river corridor regulations added on average 22 square feet (ft^2) of development per acre of river corridor, and towns without regulations added an average of 24.4 ft^2 of development per acre of river corridor over five years. This equates to 56 ft^2 per 100,000 ft^2 over five years, or 11ft^2 per 100,000 ft^2 per town per year. Finding only 4% less investment in towns with interim river corridor bylaws suggests that the bylaws do not make a significant difference in deterring encroachment. However, a number of methodological choices in this study suggests that the actual difference could be greater. Not all of the towns in the study had interim river corridor bylaws for the duration of the study period, so a large percentage of the river corridor investments in the study were not actually under bylaw regulation. Additionally, Halladay did not evaluate whether the various types of structures identified as development were permitted by right, thus it is impossible to infer to what degree the new investment in towns with river corridor bylaws truly constituted encroachment. Though the Halladay study did pursue the question of how river corridor regulations affect encroachment, overall, research on Vermont's river corridor regulations have not thoroughly examined conformance and compliance at the local level. Despite these flaws, it will be helpful to compare results from this research to that of the Halladay study.

Research Question

More evidence of how flood hazard regulations are playing out in communities can assist policy advocates and makers in determining whether to support existing flood hazard mitigation practices or to advocate for changes. This research begins to fill that gap by looking at what the enforcement of flood hazard regulations looks like on the ground. This study asks, **how does the presence of higher-standards flood hazard bylaws, implemented under Vermont's land use**

planning statute (24 V.S.A. §4424), influence the occurrence and permitting of investment in the regulated flood hazard area? This study aims to answer this question by examining the rate and nature of encroachments (through mapping-based conformance analysis) and the permitting practices of local regulatory authorities (through document analysis and qualitative assessment). These two approaches hopefully shed light on the State's progress of the State's goal to catalyze a cultural shift in favor of expanding flood hazard mitigation.

This study is not designed to evaluate the first of the State's goals—whether and how well the state might be experiencing a cultural shift toward strong aversion of flood hazard area investment. However, by documenting how often projects in the study sample are reported to the local authority and then to the State, the data does shed some light on the status of the State's second goal—i.e., how consistently property owners/developers are submitting permits to the Town and the Town sending permits to the State for review. The findings derived from the conformance and compliance analysis and from the brief assessment of the permitting context provide insight into the State's major policy question: whether the State should continue to play only a supporting role in the regulation of development in the river corridor or whether it should increase the centralization of jurisdictional power.

CHAPTER 4

LITERATURE REVIEW

Introduction

Climate change has increased the frequency, intensity, and magnitude of flood events. This increasing probability of flood events, combined with continuing encroachment in flood hazard areas that increase human vulnerability to flood events, has increased flood risk and forced greater flood disaster risk reduction efforts in states such as Vermont. In their 2012 special report entitled "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation," the Intergovernmental Panel on Climate Change incorporated a comprehensive definition of disaster risk management into their climate adaptation lexicon, describing it, in short, as processes that improve understanding of risk, reduce risk, and promote disaster response that fosters human well-being and sustainable development.

Berke, Lyle and Smith (2014) point out that of the pre-existing subfields of planning, hazard mitigation perhaps best informs the preparation of communities for climate change: it deals with fast- and slow-onset disasters, orients toward the future, and plans proactively for future needs. According to Birkmann and Pardoe (2014), land use and climate change planners' focus on how development influences vulnerability to disasters has likewise been an important contribution to hazard mitigation policy and practice. Weather and climate events create the conditions for disaster, but vulnerability is not a "characteristic of physical phenomena; rather it is shaped by human and societal processes and patterns" that lead to exposure to physical phenomena (Birkmann and Pardoe 2014, 43). Professionals charged with managing the impacts of natural disasters, whether they are influenced by climate change or not, are thus increasingly concerned with how to influence investment processes to reduce vulnerability in extreme weather events. Investment processes are influenced by the complex dynamic between private property rights and public harm prevention that inform the layers of federal, state, and local regulation. A

broader look at the evolution of federal flood management policy, the legal/cultural context of natural resource land use regulation in the United States, and the dilemma of shared governance helps situate our understanding of Vermont's own efforts to influence reduce human vulnerability to flood hazards.

Federal Flood Hazard Management

There are two important stories to tell about the history of federal flood hazard policy. The first is the story of how federal flood management practices in the United States have contributed to a high rate of development in floodplains. The second is how shared governance of flood hazard management, specifically the NFIP, has evolved. These parallel developments became more intertwined over the decades as federal policy shifted toward nonstructural measures and proactive strategies advised by higher governments but enacted and enforced by local governments.

Throughout the last century, planners and engineers have treated natural floodplains as developable land, using *nonstructural approaches* to modify the localized probability of flood with techniques such as channelization, dams, and levies. In maximizing the extent of development and agriculture in floodplains, planners and engineers built barriers that disconnected rivers from their floodplains and created a false sense of protection for homeowners. The Flood Control Acts of 1917 and 1936 facilitated this approach to flood management on a broad scale, funding large infrastructure projects that reduced floodplains' ability to convey floodwaters, regulate flood stage, and maintain their hydrological function (Christin and Kline 2017).

The first federal measures aimed at minimizing flood exposure by adapting local behavior (e.g. development restrictions, building codes, early warning systems, and buyouts) and localized stormwater management, known as *nonstructural approaches* to flood hazard mitigation, came mid-century. In 1956, Congress passed the Federal Flood Insurance Act of 1956

but never appropriated the funds to implement it (Mittler et al. 2006). In his pioneering comprehensive study of floodplain management partially inspired by the 1956 act, Murphy (1958) found very low levels of voluntary community adoption of flood hazard regulations and questioned whether widespread adoption of nonstructural approaches was possible without financial incentive or threat of financial withholding.

The NFIP emerged in 1968 but took time to evolve the financial incentive/withholding mechanism and fully engage local governments. While elements of the NFIP, such as enforcement of minimum building standards and buyout of properties in the newly mapped 100-year floodplain, began to transform floodplain policy toward a mitigation framework, the program did not require community-level flood hazard regulations until 1973 (Mittler et al. 2006). Similarly, it was not until the 1974 Disaster Relief Act that local hazard mitigation planning became a requirement for federal disaster assistance (Platt 1999). A year later, the Federal Emergency Management Agency (FEMA) was formed and charged with considering hazard mitigation in all emergency preparedness and disaster response.

Two important sources of funding for state flood hazard mitigation emerged in the 1980s. In 1980, FEMA's State Assistance Program increased state floodplain management offices' capacity to assist communities with NFIP requirements (Mittler et al. 2006). The passage of the Stafford Disaster Relief and Emergency Assistance Act in 1988 re-established the requirement that hazard mitigation planning be a condition for post-disaster aid and buyouts and established the federal cost share for federal disasters as 50% (later raised to 75%) (Platt 1999). This federal cost-share provides the financial foundation for ERAF.

Most states became involved with floodplain management in the 1970s and built their programs in the 1980s (L. R. Johnston Associates 1992). By the 1990s, States had settled into their responsibilities with assisting local communities with NFIP compliance: conducting

Community Assistance Visits,[18] helping communities develop and adopt ordinances, and helping with map modernization, as well as going beyond what was required by providing technical assistance to communities and individuals (Mittler et al. 2006). State efforts in the 1990s would must have helped improve the 1985 statistic that 52% of local government officials were not familiar with their state's flood hazard mitigation program (Burby, French, and Cigler 1985).

While the NFIP and state programs were helping mainstream flood hazard regulations that addressed inundation hazard, FEMA was failing to provide any kind of comprehensive regulation or leadership on fluvial erosion hazards (Association of State Floodplain Managers 2016). The "Final Report to Congress: Streambank Erosion Control Evaluation and Demonstration Act of 1974" provided a preliminary nationwide evaluation of streambank erosion but recommended only structural mitigation methods that would exacerbate erosion hazard. The 1999 Riverine Erosion Hazard Areas Mapping Feasibility Study determined that fluvial erosion could be mapped, but FEMA has failed to develop comprehensive recommendations for erosion hazard mapping. Finally, NFIP provided for a Zone E "Area of Special Flood-Related Erosion Hazard," but has never mapped such a zone in its FIRMs.

The NFIP has been the most important immediate checks on development in areas prone to flooding in the U.S., but by failing to provide high-quality floodplain maps for all municipalities, failing to create strong mechanisms for enforcement, promoting hard infrastructure solutions to avoid flood risk, subsidizing the true costs of floodplain development through the NFIP (Christin and Kline 2017), and providing little guidance for flood erosion risk assessment and regulation (Association of State Floodplain Managers 2016), FEMA has passively encouraged human vulnerability in the form of high-risk development in the flood hazard area. In his study of disaster governance following Hurricane Katrina, Burby (2006) called this strategy

[18] A component of the Community Assistance Program, community visits by a FEMA or state staff member provide technical assistance to the community and assure that the community is adequately enforcing its floodplain management regulations ("Community Assistance Visit" n.d.).

for flood management the "safe development paradox," whereby local governments seeking to increase the safety of a community effectively encourage development in areas still vulnerable to disastrous physical and economic loss. Tropical Storm Irene demonstrated in Vermont how devastating the legacy of federal policy—loss of floodplains, encroachment into the river corridor, and the presence of poorly adapted structures in flood hazard areas—can be to property and public infrastructure. Mitigation strategies that incorporate the river corridor and NAI principle represent a sharp break from the traditional flood risk management practices promoted at the national level. Application of federal minimum standards or Vermont's higher standards to all of the state's flood hazard areas rests on the ability of local governments to integrate them into what is arguably local communities' most impactful tool for hazard mitigation: land use regulation.

Land Use Regulation as a Tool for Hazard Mitigation

Much analysis has been done on what land-use planning tools apply to hazard mitigation. Tang et al.'s (2011) typology of hazard mitigation land use tools has been adopted as the most simple and comprehensive. It identifies eight primary tools: development regulations, building standards, property acquisition, incentive tools, education, critical public facilities policies, financial tools, and private sector initiatives. Vermont has actively engaged with each of these strategies.[19] In their study of county planners' perception of these tools, Ge and Lindell (2016) found that development regulations were perceived as both the most effective measure for hazard mitigation and the tool facing the highest impediments and second-highest cost barriers. In their research for NOAA on perceived benefits and barriers among land use planners in hazard and

[19] Though not listed in Tang et al.'s (2011) typology, Vermont could also, but does not, use real estate disclosure to better inform property owners about flood hazard (Kline and Evans 2019).

resiliency planning, Booz, Allen, and Hamilton Inc. (2010) found that fear of the "taking" issue and economic development pressure were the greatest barriers for safe development planning.

Natural resources such as waterbodies and watercourses are typically regulated through floodplain zoning districts and zoning overlays—bylaws that permit additional protection or encourage specific alternative development outcomes in addition to the underlying zoning. Since Euclid v. Ambler Realty Co. (272 US 265 (1926)) established zoning as a lawful practice, courts have struggled to clearly define a balance between the central purpose of zoning—protecting the public health, safety, and welfare—and the constitutional right to use private property for economic benefit. Floodplain regulations are a controversial planning tools because they inherently interfere with property rights, and the limitations on development are often so comprehensive in comparison to other environmental land use regulations (with the exception of wetlands protections in some states) that they are perceived as confiscatory, or a "takings" (Wright 1994). This appears to be a possible factor in Vermont, where respect for private property rights presented a statistically significant barrier to Vermont communities' adoption of river corridor bylaws (Stepenuck 2016).

The conflicts between public harm reduction and private property rights likely influence other dimensions of flood hazard regulations in addition to adoption, such as which rights are protected when and by whom, and how regulations are enforced. Despite the federal government's integration of nonstructural measures and proactive strategies into its flood hazard policies since mid-century, there remained, according to Platt (1999), "hesitation at all levels of government to enforce effective land use controls in areas of known hazard" to promote pre- and post-disaster risk reduction (102). Following the wave of constitutional decisions protecting private property rights in land use law in the 1980s and 90s, those who in theory supported land use controls for hazard mitigation typically shied away from their use, relying on alternative tools such as hazard mitigation plans (Platt 1999; Godschalk et al. 1999). Although the State of Vermont has been extremely proactive compared to other states in enabling development controls

to promote flood hazard mitigation, the State itself has refrained from imposing statewide regulation. Instead, they encouraged local control through the ERAF incentive program.

Shared Governance of Hazard Mitigation

There is a problematic mismatch between the federal government's level interest in promoting disaster mitigation policy and what they and local governments actually do to promote disaster risk reduction. Despite subsidizing flood insurance and paying the majority of disaster recovery bills, the federal government is deeply reluctant to legally require additional risk reductions. Local governments—the level government at which most land use regulation occurs, is also reluctance to implement protective policies and lacks the incentive to because the federal government foots most of the bills. This mismatch is known in the planning field as the "shared governance dilemma" (Berke, Lyles, and Smith 2014). Many federal environmental laws that address the shared governance dilemma, can be described as what Gunther Teubner (1983) identified as "reflexive law," legal framework that relies on interdisciplinary and inter-sector cooperation to solve complex societal problems. Reflexive laws address the shared governance dilemma by imposing rules that guide state and local governments but also grant them a large degree of flexibility in how compliance is achieved. These rules take the form both of mandates—laws that require compliance but do not dictate the path to compliance—and incentives—where voluntary participation results in some built-in benefit.

Shared governance helps get around the conflict between reduction of public harm and private property rights. By providing the data and a framework of support but leaving adoption of higher-standard flood hazard regulation a choice, the State of Vermont empowers communities to decide on their own how they would like to bear the burden of public harm prevention. This policy of shared governance aligns with the Association of State Floodplain Manager's interpretation of the NAI principle in that it allows communities themselves to identify acceptable levels of impact and implement policies aimed at keeping the level of harm below that threshold

(2008).[20] The NAI principle encourages communities to implement flood hazard regulations that interfere with the property rights of some in order to protect the property of others, an approach the Association of State Floodplain Managers sees as closely enough aligned with the no public harm principle in land use law that it is difficult to challenge in court.

The fact that limitations on private property use come from the community and not the State may be important to the success of local higher-standard flood hazard bylaws in Vermont, given the sensitivity of property owners to land use regulations (a sensitivity the State has engaged with throughout the fifty years that Act 250 has been in effect). On the other hand, as Mike Kline from the Rivers Program put it "neighbors don't want to regulate neighbors" (personal communication, February 2019), so town residents may not report investments they suspect are nonconforming, and zoning administrators[21] may feel pressure to permit nonconforming projects. The State of Vermont sees this predicament—the importance of community self-regulation and the concomitant unreliability of community self-regulation—as it considers policy changes that would further promote its flood hazard mitigation goals. The success of flood hazard mitigation, in Vermont and elsewhere, may be tied not only to how mandates and incentives structure roles and responsibilities in shared governance but also to which penalties result from nonconformance. Additionally, because Vermont asks towns to go above and beyond what is required for NFIP, Vermont would also need to provide its flood hazard managers with the resources to assist towns above and beyond what is required of them through NFIP.

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[20] Vermont's policy may not be as loose as that described by the Association of State Floodplain Managers: In Vermont community can write its own bylaws with no greater benefit aside from harm reduction, but if it wants to receive the incentive (17.5% matching through ERAF), the bylaw language must be what is mandated in the 2014 FHARC Rule.

[21] Recognizing that floodplain/zoning administrators are not the only ones in local government who make decisions about permitting, mention of administrators will encompass the boards they work with as well, when applicable.

Compliance Models

If Vermont seeks to improve local-level compliance with flood protection standards and processes, the strengths and challenges of the NFIP's compliance model offer an important point of comparison. A compliance model is the set of strategies that encourage voluntary adherence to requirements, strategies such as promotion, monitoring, and enforcement. In the NFIP compliance model example, it is the role of local authorities to regulated individual structures to meet the minimum NFIP standards, and the role of state flood managers to support to promote and support compliance. Communities are audited annually by state and federal authorities for whether they are fully enforcing the minimum standards. If not in compliance with NFIP requirements, communities are first put on probation, and then penalized by being withdrawn from the insurance program so that individual property owners can no longer get federal subsidized flood insurance.

It is clear that at the national scale, communities do not enforce NFIP floodplain regulations in a way that achieves 100% compliance. In their review of aggregate data and interviews with regional, state, and community staff, Monday et al. observed in 2006 that the majority of the 20,000 NFIP-participating communities are running "competent programs", estimating that 70-80% of communities had no NFIP program deficiencies or violations, or if they did, addressed them within two years (2006, viii). A related study by Mathis and Nicholson (2006) estimates that 89% of buildings in towns participating in the NFIP are properly elevated, elevation being the most important factor in preventing flood damage.

In a recent study of community compliance with the NFIP program, Flavelle and Schwartz (2020) anecdotally identified ignorance and conscious non-enforcement on the part of floodplain administrators, a reduced NFIP auditing program, and the lack of enforcement as possible reasons for the presence of non-conforming structures. Mittler et al. (2006) found that neither FEMA staff nor state floodplain management staff feel there were clear guidelines for who is responsible for enforcement actions in response to NFIP non-compliance, which the staff

believed hampered effective enforcement. Indeed, Monday et al. (2006) heard from FEMA and state floodplain management staff that FEMA does not sanction often enough, though this criticism is difficult to support with evidence because FEMA does not track the rate of compliance.

In their review of literature on compliance models, Monday et al. (2006) found that, though difficult to compare with theoretical models because of the multiple and complex levels of compliance, the NFIP's compliance model most closely aligns with the "cooperative enforcement model", which combines voluntary approaches (in the form of financial incentives) with sanctions. The cooperative enforcement model emphasizes technical assistance to support voluntary action over monitoring and inspection activity that leads to penalization. The cooperative approach appears to be effective in compliance environments such as the NFIP, where it is assumed that a) there is willingness to abide by technical standards, b) public servants value the protection of people and their property, c) resources are highly constrained, d) lack of knowledge is the principle barrier to proper enforcement, and e) the relationships are long-term. Long-term relationships and the general assumption that local authorities are well intentioned but resource constrained leads to a greater degree of discretion and flexibility in enforcement. However, Monday et al. (2006) assert that the cooperative enforcement model only works when there is a credible threat of enforcement: while technical support and leniency is likely sufficient for most communities in the NFIP, the study reports that regional and state floodplain officials do find that if the public knows they are reluctant to sanction, non-compliance levels can increase, especially in communities characterized as having recalcitrant attitudes toward NFIP compliance.

The ambiguities in FEMA's enforcement of NFIP could be attributed to a number of factors. First, FEMA believes that good flood hazard mitigation is more readily achieved when a community participates in the NFIP than when they are suspended from it, making FEMA resistant to enforcement (Monday et al. 2006). Second, as already pointed out, the role of FEMA and the role of States in enforcing penalties appear to be poorly defined. Third, the degree of

compliance that the NFIP's enforcement policies should be aiming for is not clear. Monday et al. (2006) found that neither FEMA nor Congress has articulated an optimal level of compliance with NFIP nationwide, and no state and federal programs that collect compliance data define an optimal level for comparison either. Fourth, as a result of the vagueness of compliance goals and the lack of data on compliance, it is difficult to know what balance of flexibility and enforcement would produce the highest rate of compliance. As much as they also create inconsistency and frustration, the ambiguities that characterize FEMA's enforcement may also be what keeps the model "flexible" and therefore functional.

The relationship between Vermont State flood mitigation management and communities could also be described as most similar to the cooperative enforcement model, but it differs in a number of ways. The cooperative model really shows up in Vermont only with flood hazard regulation adoption: once the bylaws are adopted, the community receives its matching amount and the incentive mechanism has been exhausted. Local enforcement of the regulations, therefore, becomes fully voluntary (except for what is required by NFIP) because there are currently no penalties for failure to implement the bylaws that affect eligibility for ERAF. This is relevant to the State's policy questions about how to improve statewide hazard mitigation because more successful risk reduction results from local-level conformance, which often comes from enforcement of higher standards, not just regulations in name-only.

Conclusion

The advancement of improved flood hazard mitigation standards in Vermont is complicated by a multi-layered model of governance and compliance. The literature on flood hazard mitigation planning indicates that tensions between private and public good, the question of what level of government is best suited to design and enforce measures that protect the public from harm, and debate over the ideal model for enforcement are not unique to Vermont.

However, overall, it appears that Vermont's approach to regulating flood hazard areas (zoning) generally follows what the literature supports as good practice in flood hazard mitigation:

- Vermont heavily promotes regulations, a nonstructural strategy that tend to reduce human vulnerability to flood hazards;
- Higher-standard regulations are more restrictive than the minimum NFIP standards, helping to close the gap between federal standards and what professionals consider adequate protection;
- Higher-standard regulations are adopted by local discretion, in response to an incentive rather than a mandate, so communities can be expected to feel more ownership;
- Regulations can be tailor-made by communities, making communities responsible for the balance between private rights and public good, which may reduce the amount of public harm-private right conflict that arises;
- The model of voluntary adoption of State-defined higher standards incentivized by ERAF aligns somewhat with the cooperative enforcement model, which may be the most effective model for floodplain management.

Together these strategies are designed to promote both improved flood hazard mitigation and good community compliance. The following twelve case studies give an indication of not only how much and what kind of investment is occurring in Vermont's flood hazard area, but the degree of community compliance with the higher standard flood hazard regulations promoted in Vermont. They thus provide examples through which to explore how flood hazard policy might be improved in Vermont.

CHAPTER 5

METHODS OVERVIEW

Goals and Objectives

With this research I sought to describe how the presence of interim river corridor bylaws (higher-standard flood hazard bylaws) influence the occurrence and permitting of new investment in the regulated flood hazard areas (FEHA and SFHA). I did this by examining the frequency and nature of investments (defined as structures, parking lots, cut and fill projects, and renewable energy installations) occurring in the regulated and unregulated flood hazard area, the frequency and nature of investments that should have triggered local review to determine rate of investment, and zoning conformance. I also looked at the permitting practices of local regulatory authorities to determine local compliance with the legal process for permitting in the flood hazard area. To conduct this investigation, I identified the twelve communities (out of Vermont's 246 incorporated towns) that had adopted some form of standardized interim bylaws (higher-standard flood hazard regulations) before 2013. Visual analysis pinpointed incidents of investment that should have triggered a local discretionary process in six of the twelve towns. These six towns became case studies of what happens with the local permitting process when triggered by a new project.

I pieced together how each town in the study sample dealt with new projects through a stepwise analysis. The research consisted of six primary phases: 1) sample criteria development and sample selection, 2) local bylaw coding, 3) spatial data collection of potential incidents through visual analysis, 4) incident conformance analysis and compliance cross-check with state records, 5) incident permit review, and 6) interviews with local floodplain administrators and regional flood managers. In addition to documenting new investments in the visual analysis, I also recorded removals of investments to account for net land use change. Because each of these

six stages produced valuable data in their own right, the results and findings of each stage are fully described along with the respective method.

This study takes a deductive approach to understanding how FEHA areas were regulated by municipalities in Vermont: I have analyzed the data collected against principles and requirements outlined by the applicable state and local law. In so doing, I assumed that a) new investment conforms to zoning code, and b) any new investment locally permitted complied with the requirement that it be reviewed at the state level. Findings that are contrary to these inferences therefore suggest that proper local interpretation and enforcement processes may have been misapplied to flood hazard regulations.

In the interest of producing research that is useful to the environmental conservation, hazard mitigation, and planning communities in Vermont, I sought advice on the research design and received access to data and resources from stakeholders: the Vermont office of Conservation Law Foundation, the Vermont office of The Nature Conservancy, and the Vermont Rivers Program. Additionally, semi-structured interviews or email consultation conducted with staff at the Vermont Natural Resources Council, Two Rivers—Ottauquechee Regional Commission, and the Vermont Center for Geographic Information yielded important insight into aspects of hazard mitigation planning in Vermont and the availability of data.

Research Parameters for Quantitative Phases

Population: Vermont's 246 towns

Case unit of analysis: 1 Vermont town

Dependent variable A: Number and square foot area of investment incidents (structures, parking lots, cut and fill projects, and renewable energy installations) in the regulated flood hazard area, and number and square foot area of incidents of investment removals.

Dependent variable B: Number and square foot area of investment incidents (structures, parking lots, cut and fill projects, and renewable energy installations) that should have triggered local conditional review.

Key independent variable: Presence of higher-standard flood hazard zoning bylaws (applicable to the SFHA, and to the FEHA where regulated).

Study time frame: Imagery dates from July 1, 2011 to July 1, 2017. Various time frames (3- or 5-year spans) were used to accommodate for different bylaw adoption dates. Each sample town will have its results normalized by the number of years in its study time-frame, so the results will be reported as the number of incidents per year in each town. This is not a year-to-year time series study.

Sample: Twelve towns with state-recognized interim river corridor bylaws (higher-standard flood hazard bylaws).

Sample characteristics: Towns with interim river corridor bylaws that approximate the State's 2009 model flood hazard bylaws. Eight towns that adopted flood hazard zoning prior to January 1, 2011 will use imagery for analysis: Braintree, Cabot, Plainfield, Roxbury, Sharon, Troy, Vernon, and Worcester. Four towns that adopted river corridor zoning between January 2011 and July 2012 will rely on a combination of LiDAR and imagery for analysis: Williston, Richford, Shaftsbury, and West Rutland.

Incident: New investment or removal of investment in the flood hazard area. The total square foot and number of incidents will be normalized by the number of years in the study time frame (based on the imagery) and by the total area of regulated flood hazard area in the town in 100,000 ft^2. The term "Incident" will represent any activity in the SFHA, the regulated FEHA, and the unregulated river corridor. Incidents that should have triggered a conditional permitting process will be identified as such.

Limitations of the Study

The availability of data limited both the type of study that could be conducted and the precision of the study. First, sufficient data does not yet exist to do quantitative statistical analysis of a census of cities and towns with higher-standard flood hazard bylaws because too few towns had adopted such bylaws prior to the period that visual analysis was possible (see Visual Analysis Data Selection). The study lacks the external validity that can be achieved by a large, statistically significant sample size and is therefore is not generalizable across the state of Vermont. The findings of this study therefore may not reflect the experiences of towns in Vermont as a whole.

Second, the study does not draw conclusions about why a town interprets and enforces their flood hazard regulations the way they do because projects couldn't be traced back to the precise logic of the permitting decisions made by the local zoning administrator or the review board, and also because the small sample size did not allow the testing of independent variables (such as development pressure or town government characteristics). The study therefore offers limited insight into whether a town planning/zoning authority is the most effective actor for protecting the flood hazard area from new investment. However, the small sample allowed for better quality visual analysis and allowed the research to attempt to dig into each town's process for permitting in the flood hazard area. Yin (2013) suggests that research questions asking "how" tend to lead to case studies "because such questions deal with operational links needing to be traced over time, rather than mere frequencies or incident" (10). Though the study will not provide answers as to why certain investments occur and are permitted in the flood hazard area, it will shed light on local context in which permitting happens (or does not happen).

Third, The study was only able to examine the frequency of incidents of investment and removal within the time period studied. Because it does not measure investments in the regulated flood hazard area prior to the adoption of higher-standard flood hazard bylaws, it cannot explain how adoption of these regulations influenced the rate of investment.

Fourth, as much as it would have helped paint the full picture of the local permitting process, this study also did not document how many or how often new investments were discouraged or not permitted by the local zoning authority.

Fifth, the bylaw analysis showed that only three of the twelve towns that met the sample criteria for this study actually applied their interim bylaws to the State-mapped FEHA in their town, and not just FEMA-mapped areas. Furthermore, in one of those three towns with FEHA bylaws, FEHA bylaws applied to only select rivers and streams within the town boundaries because early FEHA mapping was done at the request of towns and towns did not always request mapping for all reaches. For example, the FEHA applied only the Ayers Brook reach in Braintree, not the Upper Branch or the Third Branch of the White River. Therefore, this study only analyzed a very small percent of area that was exclusively regulated FEHA, which prevented meaningful comparison between the regulated FEHA, unregulated river corridor, and the SFHA.

The completeness and accuracy of the research's findings was limited by the availability of complete floodplain data and detailed public records. Not all towns have publicly available updated digitized FEMA FIRMs. Digital maps of the SFHA and floodway came from a state-generated shapefile that included the most accurate flood delineation available to the State; floodway data was available for only three of the twelve towns sampled (Worcester, Williston, and Plainfield). To increase the validity of the findings, Vermont flood managers reviewed the incidents of investment identified by the visual analysis to correct for visual interpretation error. They did not, however, review all the incidents that occurred in the regulated flood hazard area, so there may be a wider margin of error in the larger investment and removal dataset and the list of incidents that should have triggered discretionary review may be smaller than they were in reality.

The findings on conformance represent only a partial analysis of zoning conformance. They confirm whether the type or subtype of the investment conformed was permissible in the zone, but do not confirm whether the investment conformed to all that is stipulated in the zoning

bylaw, such as first floor elevation. Full conformance status could only be established by ground-truthing the project.

Finally, the data collection for this study began in late 2019 and ran through April of 2020. The permit analysis phase began in early March of 2020, just as the outbreak of the Corona virus/Covid-19 pandemic began to affect the ability of Vermont public offices to access their documents. The permitting data collected for this study may thus be less than what was available under normal conditions.

Research Bias

As a planner-in-training with a strong belief that climate change is intensifying weather patterns and changing natural systems in a way that increasingly puts the built environment and human lives at risk, I believe the private and public benefits of flood hazard area protection outweighs the potential personal or economic harm inflicted on individuals in limiting their property rights. I have therefore approached this research with the intent of identifying weakness in the legal or governance structure designed to protect the river corridor may have failed, so that protection can be strengthened. This may lead me to overidentify non-compliance where visual data or application of the zoning is ambiguous. To correct for this, I noted ambiguity so that incidents where personal bias may be affecting the results may be controlled for.

While I and the stakeholders I communicated with have a strong interest in the protection of flood hazard areas for the purpose of both hazard reduction and conservation, it is my impression that parties interested in this research do not have a vested interest in any particular finding. I believe each stakeholder wants a better understanding of encroachment rate and regulatory practices in local flood hazard areas to inform their work in reaching goals already stated in state policy or their organizations' agendas. Conservation Law Foundation is motivated to understand the efficacy of river corridor zoning bylaws specifically to inform future climate-adaptation-related policy advocacy (Mihaly 2019). If the research finds that local towns are not

able to effectively protect river corridors according to their flood hazard bylaws, the organization may decide to advocate for a different approach, such as the State playing a larger role in regulating the corridor. For Vermont ANR's Rivers Program, the overarching goal of this science-based regulatory program is to change peoples' land use expectations over time (see Research Significance). The state wants to anticipate the need for the program to expand while at the same time acknowledges the limitations of the state budget to grow the program. Understanding towns' current capacity for managing this program is important for those considerations.

CHAPTER 6

METHODS & RESULTS

Characteristics of Sample Towns and Reasons for Selection

To maximize the amount of data available for analysis, the sample selection included as many towns as met the sample criteria. To ensure that the incidents reviewed by the study weren't likely to have been approved before the bylaws went into effect, I first selected only towns that passed their "interim" bylaws at least six months prior to the summer of the study start year (2011 or 2014; see Visual Analysis Method section regarding study period), providing a six-month buffer for projects started under old bylaws to work their way through the system.[22] Using the Community Reports posted on *floodready.vermont.gov*, which compiles Vermont towns' ERAF actions and dates, I identified fifteen towns that adopted "interim" bylaws prior to January 1, 2011 (so their visual analysis relied solely on 2011 – 2016 NAIP).

To increase the likeliness of actually documenting incidents of investment, I then excluded towns from the sample with populations less than 500 residents according to the 2010 census, as less-populated towns in Vermont were less likely to have developments to analyze.

A number of towns were later culled from the sample during the bylaw analysis phase because they either did not have their relevant bylaws accessible via the internet, they deviated dramatically from the State's 2009 model regulations, or they were otherwise difficult to interpret (coded in Appendix B: Towns Excluded from Sample as "Bylaws Unsatisfactory"). For example, the Town of Lincoln, which otherwise met the sample criteria, zones both a flood hazard area whose boundaries align with the SFHA and a River Overlay Area, whose purposes relate to both

[22] Six months was arguably not a large enough buffer; late in writing this paper I discovered that one of the incidents identified that should have triggered discretionary review was permitted in 1999, at least four years prior to the town's adoption of interim river corridor bylaws.

habitat protection and fluvial erosion reduction. The added complexity of these multiple standards was cause for excluding the town from the sample.

After the first round of sample selection produced only eight towns, I expanded the sample pool to the sixteen towns that adopted prior to January 1, 2014 and use a combination of NAIP and LiDAR for their analysis. This produced an addition four sample towns.

Of the twelve total sample towns, eight were studied under a 5-year time span and four studied under a 3-year span.[23] Table 1. lists the imagery types and years studied for the final sample towns. Appendix B: Towns Excluded from Sample lists the 19 towns initially eligible that were not included in the sample and the rationale behind their exclusion.

Table 1. Towns Selected for Study Sample

Town	Interim RC adoption date	Population (2010 census)	Imagery used	Analysis span (years)
Cabot	2/10/2010	1,322	2011 to 2016 NAIP	5
Plainfield	3/2/2010	1,392	2011 to 2016 NAIP	5
Braintree	3/14/2010	1,105	2011 to 2016 NAIP	5
Worcester	3/15/2010	900	2011 to 2016 NAIP	5
Williston	3/22/2010	9,341	2011 NAIP to 2014 LiDAR	3
Vernon	9/27/2010	2,237	2011 to 2016 NAIP	5
Troy (incl. North Troy)	10/18/2010	2,072	2011 to 2016 NAIP	5
Roxbury	12/6/2010	734	2011 to 2016 NAIP	5
Sharon	12/6/2010	1,413	2011 to 2016 NAIP	5
Richford	3/6/2012	2,458	2014 NAIP to 2017 LiDAR	3

[23]Sample selection could be improved in several ways in a future study. I accidentally analyzed Williston over a 3-year period instead of the 2011-2016 5-year period that was available. Second, a number of towns initially excluded because I had difficulty interpreting the bylaws (North Bennington, Readboro, and Bolton), and could be included in the sample.

West Rutland	6/11/2012 (amended)	2,454	2013 LiDAR to 2016 NAIP	3
Shaftsbury	8/6/2012	3,487	2014 NAIP to 2017 LiDAR	3

The mean population of the towns in the sample is 2,409, which aligns with the state's 2010 census mean town population of 2,544. However, a smaller median town size of 1,743 reflects a bias in the sample toward smaller towns, the result of a higher rate of adoption of interim river corridor bylaws among small towns, (adopters prior to 2014 mean town size = 1,958, median town size = 1,347).

Vermont as a whole does not experience high development pressure relative to its neighboring states. Development pressure concentrates around the largest city of Burlington and around ski resorts. Williston (as a suburb of Burlington), Richford, and Troy (as towns adjacent to Jay Peak Resort) aside, most sample towns were expected to have low incidents of investment in the SFHA and river corridor due to their low population and lack of development pressure.

The twelve sample towns are distributed across nine of Vermont's fourteen counties, as seen in Figure 3. Four sample towns—Roxbury, Braintree, Sharon, and Worcester—are located in mountain ranges characterized by steeper slopes and narrower river valleys. On the whole, however, the sample towns are well distributed between towns with larger, older rivers and wider flood plains, such as Vernon on the Connecticut River and Richford on the Missisquoi River, mid-sized rivers in hilly landscapes such as the Winooski River in Plainfield or Cabot, and flashier (quick-to-flood) streams characteristic of the more mountainous towns.

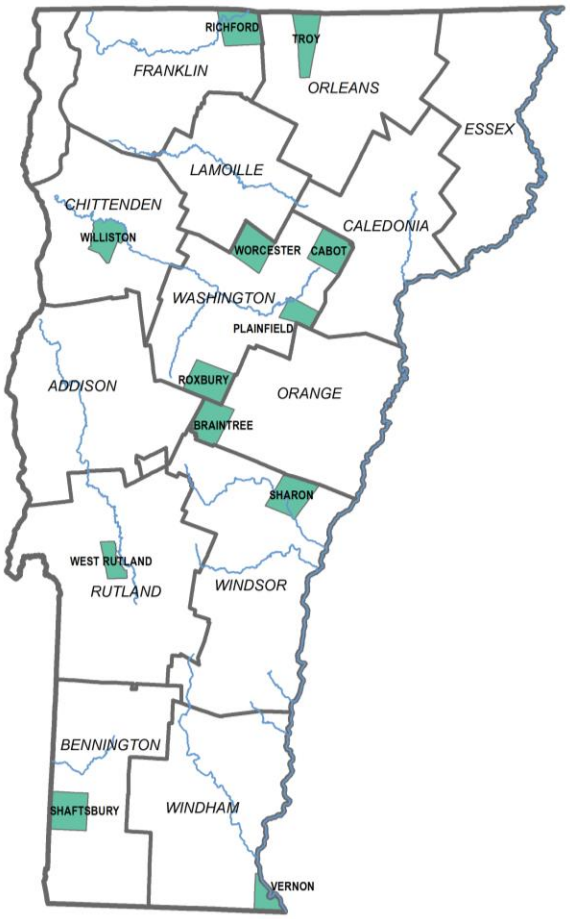


Figure 3. Geographic Distribution of Sample Towns Across Counties

Bylaw Analysis Method

To streamline the later compliance analysis stage, it was important to read and code each sample town's bylaws. For the most part, the standalone inundation regulations and flood erosion hazard sections of bylaws followed the boilerplate language of the 2009 State flood hazard model bylaws. For each bylaw I coded each use as permitted, prohibited, conditional, exempt, and no mention. I separated out a number of uses that applied differently in the floodway and FEHA (when applicable) than they did in the SFHA outside the floodway. Where towns regulated additional uses not covered by the model bylaws, I created a new use category.

Before completing this analysis, I checked the amendment dates of each set of bylaws to see if changes were made over the study period. This was the case with Cabot (2010 v. 2013) and

Richford (2010 v. 2012), but there was no indication any of the language pertaining to flood hazard areas had changed. The town of Richford's different flood hazard area regulations for the village and for the rest of town were accounted for as well.

Bylaw Analysis Results

As previously described, the 2009 flood hazard model bylaws' higher-standards prohibit a number of uses formerly permitted in the SFHA, including a) new structures (unless they are replacement), b) storage/junk yards, c) new fill (except when elevating structures to BFE), d) building utilities, and e) critical infrastructure. Accessory structures are expressly prohibited in the floodway and are prohibited in the river corridor/FEHA if they are over 500 ft^2. Of the uses permitted in the SFHA and FEHA/river corridor, the model bylaws require discretionary review for a) substantial improvements, relocation, and floodproofing of existing structures, b) replacement structures, c) accessory structures greater than 500 ft^2 (except in FEHA/river corridor), d) at-grade parking for existing structures, e) on-site water and septic systems; and f) public utilities (among other uses not visually detectable).

Bylaw analysis found that the study sample generally follow this 2009 template closely. Significant deviations from the state's model include the following:

- Two towns omit mention of parking;
- Three towns permit by right accessory structures greater than 500 ft^2 in the SFHA outside the FEHA and floodway;
- Five towns permit by right on-site water and septic systems;
- Three towns omit mention of critical facilities, new or replacement storage tanks, and building utilities in their bylaws even though they are mentioned in the model bylaws;
- Five towns omit mention of building removal (exempt in model bylaws); and

- Some towns have adopted language absent from the model bylaws related to public projects functionally dependent on stream access or stream crossing, storage for floatable/hazard/toxic materials, flood walls, and quarrying.

The full results of the bylaw coding exercise are provided in Appendix C: Bylaw Analysis.

Identifying nuances in the bylaws not only allows for more accurate analysis of the compliance of new uses identified through visual analysis, it also demonstrates that when given the choice, towns do not wholesale adopt the standard language of the State. Some have created less stringent regulations; others went beyond what is proffered by the State. These variations demonstrate community ownership over the terms of local flood hazard mitigation. Some towns, however, will need to update their bylaw language and the lands to which the regulations apply to match or exceed the current (2018) State model if they intend to continue to qualify for the full state reimbursement of emergency assistance.

Bylaw analysis also showed that four of the twelve towns did not have town-wide zoning. This is significant because towns that do not have zoning may have less practice and culture around permit review and enforcement. Residents of communities without zoning may also have a more difficult time understanding that there are regulations that might apply to them if they are not used to not used to going to the Town for permits.

Visual Analysis Method

Visual analysis data selection

I conducted the visual analysis using data layers sourced from the Vermont Center for Geographic Information (VCGI) and from the Rivers Program. The only data source for statewide imagery taken in a single year is the National Agricultural Imagery Program (NAIP) published in

2011, 2014, and 2016.[24] NAIP imagery is a federal product in natural color (RGB and near infrared) made available by the VCGI as ported to a Vermont State Plane projection. The years 2011 and 2016 were chosen as the primary start and end dates for the visual analysis because 2016 was the most recent publication of the NAIP data and pairing that with a start year of 2011 provided the greatest number of years of analysis (5 years) without starting earlier than the 2009 introduction of the State's flood hazard model bylaws. The 2016 NAIP imagery is published at 0.6 meter resolution, the 2011 imagery at 1 meter resolution. The NAIP for the year 2016 is published with false color (IR band) and Normalized Difference Vegetation Index (NDVI) layers that can aid in mass/biomass edge detection. Because NAIP is a "leaf-on" dataset, it can be inferred that all images were captured during summer or fall months. Though this helped situate the timing of the imagery, leaves on the trees compromised the accuracy and precision of visual detection and identification.

Vermont's Quality Level 2 (0.7 m resolution) Light Detection And Ranging (LiDAR) elevation data was also used to expand the sample to towns that adopted interim river corridor bylaws prior to January 1, 2014. A 3-year span was adequate for collecting land use change data. Vermont's LiDAR data is available as Digital Elevation Model (DEM), Digital Surface Model (DSM) or normalized Digital Surface Model (nDSM). To be able to interpret structures from elevation data, I chose to use the nDSM data format, a "composite 'normalized' digital surface model that depicts the difference between the surface (DSM) and bare earth (DEM) models, representing height of features" ("Elevation" n.d.). When using LiDAR, which displays topographical change in grayscale but does not depict color of the surface at all, it was nearly impossible to identify surface changes such as the creation or removal of a parking lot (see Figure

[24] NAIP imagery was taken in 2018, but according to the VCGI, the reliability of the imagery was compromised by the 2019 government shutdown, weather, and other factors (Tim Terway VCGI, personal communication, June 2019).

4 for an example of LiDAR quality and the absence of paved surface). For a summary of data sources, description, and quality, see Appendix D: Visual Analysis Data Sources.

Figure 4. New garage in SFHA seen NAIP, absent in LiDAR

The resolution of the imagery and changes in vegetation between image layers often made it difficult to identify the nature of an incident of change, and sometimes even whether a change had happened at all. I therefore used Google Earth Pro or other NAIP imagery from other years to confirm whether a change had indeed occurred and to get a clearer picture of the nature of incident (see Figure 5 for examples of the image quality and use of Google Earth Pro to confirm interpretation). Sometimes it was necessary to tilt the perspective of the Google Earth Pro tool to understand whether what looked like a possible incident in 2D had height (this came in handy, for example, when what looked like a shed was in fact a log landing).

Figure 5. Cabin in SFHA and FEH seen with NAIP imagery and Google Earth Pro

Additional visual analysis layer selection

The Vermont Open Geodata Portal provided statewide town boundary, river corridor, and hydrology GIS layers. Ned Swanberg at the Rivers Program provided the SFHA and floodway data.[25] See Appendix D: Visual Analysis Data Sources for the visual analysis data names, descriptions, and caveats about quality.

Visual analysis procedure

I used ArcMap GIS software to conduct the visual analysis. I created a map for each sample town that included the universal analysis shapefiles (corridor, flood, hydrology) and the imagery specific to the town. The end-year layer was layered over the start-year layer and toggled on and off while scanning the extent of mapped river corridor or SFHA within the municipal boundaries. When a visual change between the two visual layers presenting as a structure or surface change was detected, I checked Google Earth Pro for confirmation. If the observation was confirmed, I used the editor "create feature" tool to create a vector polygon feature equal in area to the footprint of the incident. I chose to not document changes to utility poles, roads, road infrastructure (such as bridges and culverts), stream infrastructure (such as dams, levees, jetties, or pilings, etc.), vertical additions, or parks and park sodding in the visual analysis because they were more difficult to detect and/or were more likely to represent a public, as opposed to private, investment.

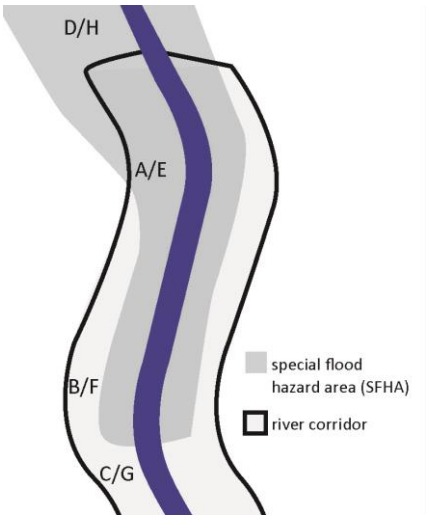
I documented incidents of new investment in the mapped SFHA and river corridor in an original shapefile. If the incident was partway in the river corridor only or partway in the SFHA

[25] FEMA's official data National Hazard Datalayer, which should provide flood zone, base flood elevation, and floodway status, does not include digitized FIRMs for all parts of Vermont. The layer provided by Swanberg was created from data provided by GIS staff at Regional Planning Commissions around the state, who have "cobbled together, 'rubber-sheeted', geo-rectified and 'heads-up' digitized vector polygons of [flood] data…" (Ned Swanberg personal communication, November 2019). Though unofficial, this layer provides a layer of accuracy not afforded by the official FEMA data.

only, I only counted only the section of the incident within the bounds of the corridor or SFHA. If the incident was half in one of the layers but fully in the other, I mapped and counted the full area of the incident. All incidents of development or removal were coded during visual analysis for the attributes in Table 2 (See also Appendix E: Coding Protocol).

To assist with the later compliance analysis phase, each incident was also coded into a "zone" that identified it as being situated in the river corridor, the SFHA, or both (see Figure 4 in Table 2). These zones distinguished between incidents occurring in towns that applied their "interim" bylaws to the FEHA and those that did not.

Table 2. Visual Analysis Data Collected

Attribute	Method of Interpretation	Unit/Code Category
Town name		
Size of incident	GIS-generated geometry calculation	ft^2
XY location	GIS-generated geometry calculation	Decimal degrees Projection: NAD 1983 StatePlane Vermont FIPS 4400
Add-remove type	Visual analysis	Add Replace Remove
Incident type	Visual analysis	Structure Driveway Renewable energy Cut Fill
Zone	Visual analysis  Figure 6. River Corridor and Special Flood Hazard Area Zones for Visual Analysis	A - zoned for FEHA, in RC & SFHA B - zoned for FEHA, in RC (outside/bordering SFHA) C - zoned for FEHA, in RC (SFHA unknown) D - zoned for FEHA, in SFHA (outside or no RC delineated) E - not zoned for FEHA, in RC & SFHA F - not zoned for FEHA, in RC (outside/bordering SFHA) G - not zoned for FEHA, in RC (no SFHA delineated) H - not zoned for FEHA, in SFHA (outside or no RC delineated)

Visual Analysis Results

Activity in regulated flood hazard areas

Visual analysis identified 63 incidents of investment or removal at 61 locations in the SFHA and river corridor (whether regulated or unregulated) in the twelve sample towns.[26] Of the total 63 incidents, 22 incidents occurred in the unregulated river corridor, leaving 41 in the regulated SFHA and FEHA. Of these 41 incidents in regulated zones, two-thirds (63%) of the land use change was addition, 17% was removals, and 12% was replacements (see Figure 7 for distribution of add-remove type). It is likely that replacements actually represent a larger proportion of the incidents identified, as the poor quality of Google imagery prior to 2011 may have obscured some pre-existing structures. The 7% of incidents categorized as Other in Figure 5 were cut or temporary fill projects.

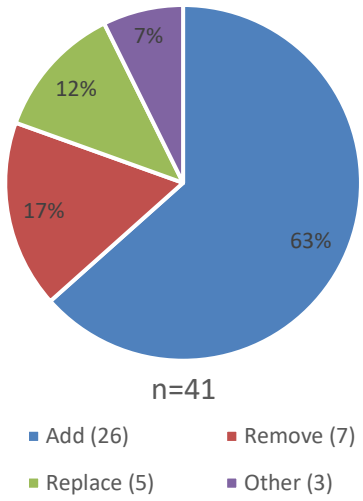


Figure 7. Distribution of Incidents in Regulated FEHA and SFHA by Addition or Removal Type

[26] I included incidents the state had reviewed that I had not caught in my visual analysis, but only if I myself could detect the change in the visual analysis.

The 31 incidents characterized as added or replaced constitute the incidents of investment.[27] Over 81% of these were structures (see Figure 8). Enlarging or surfacing of driveways represented 13% of these incidents, and ground-mounted solar panels the remaining 6%. Of the 25 structures that were added or replaced, nearly half (48%) of them are accessory structures or greenhouses, 32% are primary residential structures, and 20% are public/commercial non-residential structures or tractor trailers (see Figure 9).

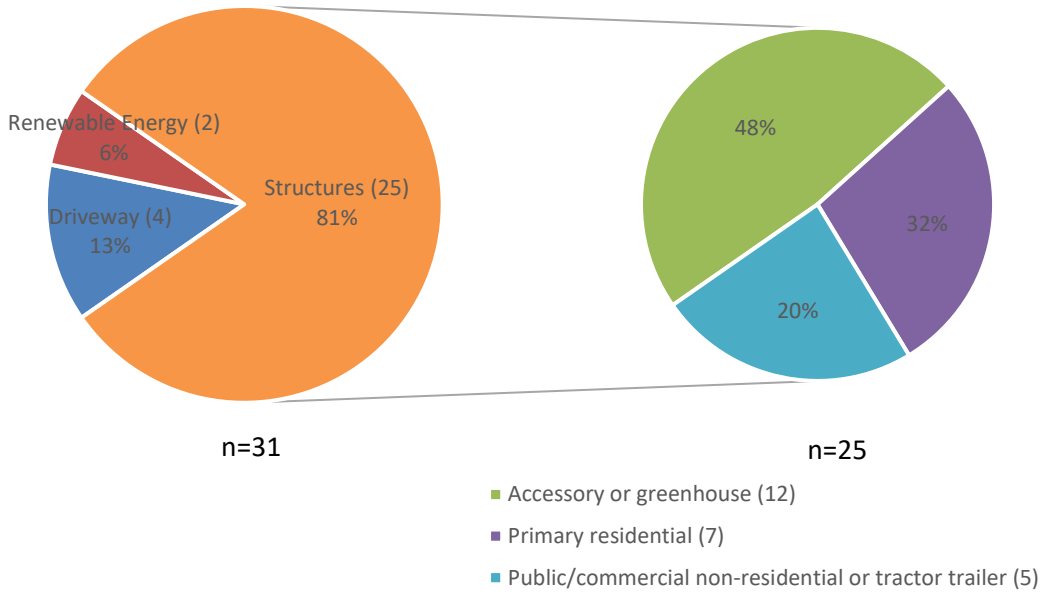


Figure 8. Distribution of Investments by Type and Breakdown of Structures by Type

Notably, none of the primary structures appears to be new and unquestionably in the flood hazard area (see Table 3).

[27] "Cut" activity (quarrying) was overlooked by this study as an investment and wasn't reviewed for whether they should have triggered discretionary review. Future studies should include excavation and quarrying in their analysis.

Table 3. Breakdown of Primary Residential Structures Appearing in the Regulated Flood Hazard Area as Additions or Replacements

Primary residential structure type	Characteristics
Mobile or manufactured homes	2 – replacement 1 – repopulation of campground
Fixed residential structures	2 – replacements 1 – new (appears in confusing section of SFHA digital layer, may not be in SFHA) 1 – new (obtained FEMA-issued letter of map amendment prior to building)

The 7 total incidents of removal identified were mostly barn removals, with 3 shed or garage removals, and 1 (possible) house removal. Based on the calculation of square foot investment and removal per year in the regulated areas, investment is happening alongside removals a little over three times as often (3.25:1). This means that although the footprint of structures being removed is significant, new investment greatly outpaced disinvestment from the flood hazard areas during the study period.

To demonstrate the relative density of investment between towns, I normalized the incident (number and total square footage of incidents) per year and per 100,000 ft^2 of the regulated flood hazard area. Normalization of a dataset transforms variables measured in areas with different universe values into a standard form for analysis.

Table 4 shows the rate incidents of investment (additions and replacements) in the SFHA and FEHA by town in both number of structures and square foot area. Only the 10 towns that had incidences of investment in the regulated flood hazard area are shown (n=0 for Williston and Shaftsbury).

Table 4. Rate of Investment in Regulated Flood Hazard Areas by Town, from highest to lowest ft^2 incident rate

	# of incidents			ft^2 of incidents		
	#	/year	/year /100,000 ft^2 regulated area	ft^2	/year	/year /100,000 ft^2 regulated area
Town						
Braintree	2[28]	0.4	0.010	32,756	6,551	161
Vernon	6	1.2	0.013	27,476	5,495	59
Richford	2	0.7	0.005	4,816	1,605	13
Sharon	8	1.6	0.015	6,996	1,399	12
Troy	4	0.8	0.005	9,042	1,808	12
West Rutland	4	1.3	0.008	5,026	1,675	10
Roxbury	2	0.4	0.022	779	155	8
Plainfield	1	0.2	0.004	642	128	3
Worcester	1	0.2	0.003	877	175	3
Cabot	1	0.2	0.001	464	93	<1
Total	31				1,908 ft^2 /town	

The average amount of ft^2 added and replaced in the regulated flood hazard area, per town, disregarding how much regulated flood hazard area in that town, was 1,908 ft^2 per year—about the footprint of a three bedroom house. The median for the ft^2 of investment per year per 100,000 ft^2 of regulated area across the 10 towns with incidents is 11 ft^2, equivalent to around 2 ft^2/acre. Most of the towns added investment to their regulated flood hazard areas at a similar rate: excluding Braintree and Vernon, the sample ranged from 1 to 13 ft^2 per 100,000 ft^2 per

[28] ~40 separate RVs in an RV park were counted as a single structure

year.[29] Interestingly, the normalized rate of 11 ft^2 per year aligns also with Halladay's (2018) finding of 11ft^2 per 100,000 ft^2 of development in regulated and unregulated river corridor per town per year (which did not apply in that particular study to the SFHA outside of river corridor).

Activity in the unregulated river corridor

There was also activity in the sample towns' unregulated areas of river corridor. One incident was a removal. The majority of investment activity in the river corridor related to structures (78%), with some driveway activity (13%) and minimal cut and fill activity (4% each) (see Figure 7). Of the ten towns that did see new investment in their unregulated river corridor, the average investment covered 902 ft^2 per town per year, less than half the square foot area of investment occurring each year in the regulated flood hazard zones. Similar to investment in the regulated flood hazard area, over three-quarters of those investments were structures; unlike in the regulated flood hazard area, however, the vast majority of these structures were new, including up to four new residences or public buildings.

[29] Braintree is the most significant outlier, but most of the investment can be attributed to the repopulation of a campground after Tropical Storm Irene, without which the rate of added investment would probably be in the normal range. The town of Vernon does appear to be a legitimate outlier in how much investment it added to the flood hazard area, but as mentioned previously some structures may have been counted due to poor quality map data for analysis and much of the square-foot area of investment in Vernon is attributed to a large commercial structure permitted under Act 250. The town of Cabot's low incidence rate is likely distorted by the disproportionate amount of lakes and ponds mapped as SFHA.

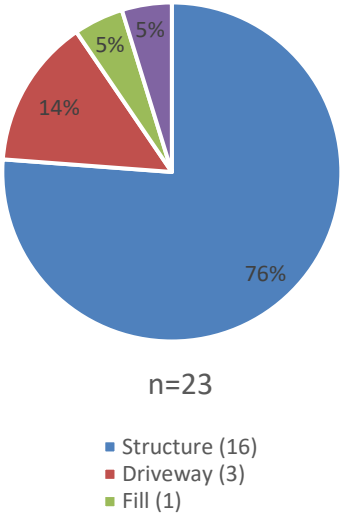


Figure 9. Incidents of Investment Occurring in Unregulated River Corridor

In summary, the data on the frequency and nature of all investments occurring in the regulated and unregulated flood hazard area shows that there is a small amount of investment happening in the regulated flood hazard area—around 11 ft^2 per 100,000 ft^2 or 2 ft^2 per acre of regulated area in most towns. The absolute rate of investment in the regulated flood hazard area is lessened somewhat by the removal of investments. Most investment activity in the regulated area is the addition of structures, the majority of which are accessory structures—projects that typically need only limited review. Although the rate of investment is less in the unregulated river corridor than it is in the regulated flood hazard areas, what investment is occurring in the unregulated river corridor is significantly more likely to be a new addition. Despite being a registerable concern for survey respondents in Halladay's (2018) survey about barriers to enforcement and a concern a about land use regulation as a planning tool in general, development pressure appears to be a minimal factor in each of the sample towns with the exception of Williston—who had very little activity in the flood hazard area anyway. Williston is the only town in the study sample to have a population growth rate over 1% (at 1.4%), and in fact, in seven of the twelve towns, population growth was negative. As the following compliance analysis

shows, what investments were occurring in the regulated flood hazard area that merited discretionary review were minimal.

Conformance Analysis Method

Describing the frequency of investments and removals can give an idea of the rate and nature of land use change in the regulated and unregulated flood hazard area, but to understand the relationship between intent of higher standards and what occurs in reality it is important to study how frequently investment activity requires conditional permits and whether and how those permits are issued.[30] To measure the conformance of the investment activity to local bylaws, I selected from the 31 incidents of investment (addition or replacement) identified as having occurred in the regulated FEHA and SFHA the incidents that should have triggered local discretionary review, and by default, State-level review.[31] This coarse-grained analysis looked simply at conformance with land use regulations based on structure size and type; it did not assess compliance with elevation or design standards.

If an incident met any of the following conditions, I judged it to comply and removed it from the list of incidents that would require bylaw scrutiny:

The incident

1. required ACT 250 review according to the floodplain development reviews spreadsheet provided by the Rivers Program;
2. was 450 ft^2 or smaller (this action was designed to remove accessory structures smaller than 500 ft^2 using a 50-foot margin of error);

[30] In some circumstances removals also require discretionary permits. I chose to not review removals for conformance and compliance because Vermont flood hazard mitigation stakeholders are overwhelmingly concerned with new investment.

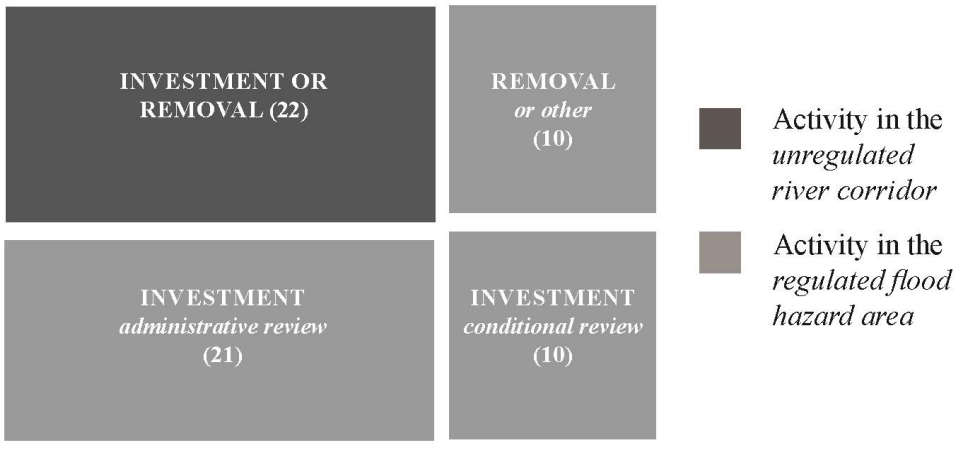
[31] I chose to not study investment activity that triggered administrative review because I originally intended to study the conditional permit documents for permitting rationale, which in the end was not possible.

3. was issue a map amendment based on a FEMA-issued LOMA;
4. was discovered to be an allowable use after further visual examination (e.g. an agricultural use or a recreational vehicle); and
5. was exempted or permitted by right, or the particular use was omitted from the town's bylaws (e.g. solar installation, driveway).

This process of exclusion considered simultaneously the incident and structure type, the regulated area the incident occurred in (SFHA, floodway, or FEHA), and whether a detailed study of the floodway was missing. I flagged the remaining investments as projects that would have required discretionary review (activity that is conditional or prohibited).

Conformance Analysis Results

Of the 63 incidents of activity in flood hazard areas, there were 31 investments that occurred in the regulated SFHA and FEHA but only 10, or one-third of , were found through the conformance analysis to be projects that should have triggered conditional permit review or permit denial (see Figure 10). The majority (68%) of them were small enough or of a nature that they did not require scrutiny at the local level, though one was a new investment was a commercial building large enough to require Act 250 instead of local review.



n = 63

Figure 10. Distribution of Activity in All Flood Hazard Areas by Permit Process Type

All 10 incidents that according to local bylaw potentially should have triggered conditional permit review were structures: a mix of mobile homes, permanent residential structures, garages, public buildings, and larger accessory structures such as a cabin and a yurt, as shown in Table 5. These structures generally broke down as four accessory structures and six replacement structures.

Table 5. Incidents of Investment in Regulated Flood Hazard Areas that Should Have Triggered Local Conditional and State Technical Review

Town	**Character of Structure**	**Zone**	**Bylaw Field**	**Area ft^2**
Braintree	2 non-residential structures in RV park	A (SFHA)	Replacement structure	5,548
Plainfield	Manufactured home	E (SFHA)	Replacement structure	641
Sharon	Manufactured home	B (FEHA)	Replacement structure (likely)	1,082
Sharon	Attached garage or substantial improvement and stand-alone shed	B (FEHA)	Substantial improvement or accessory structure >500 ft	1,467
Sharon	Residence over garage	B (FEHA)	Replacement structure	1,039
Sharon	Residence	A (FEHA & SFHA)	Replacement structure	1,689
Troy	Attached garage	H (SFHA)	Accessory structure >500 ft^2	1,059
Troy	Yurt, replacing small building	E (SFHA)	Replacement structure	2,017
West Rutland	Garage at public facility	E (SFHA)	Substantial improvement or accessory structure >500 ft^2.	3,072
Worcester	Cabin (likely)	A (FEHA & SFHA)	Accessory structure >500 ft^2	877
Sample total per year				*3,852*

Accessory structures are defined in each of the local bylaws as structures that are detached from and incidental and subordinate to the principal structure on the lot; structures must also be located on the lot and related to primary use of the lot. Troy and Richford are the only towns in the sample that require conditional review of accessory structures in the SFHA, but the three towns that include FEHA regulations (Braintree, Sharon, and Worcester) do require conditional review of accessory structures in the FEHA. Accessory structures that should have triggered review showed up in Troy's SFHA and Worcester and Sharon's FEHA.

Replacement of primary structures was the most common type of incident that should have triggered local and state review. The majority of replacement structures showed up in Braintree and Sharon, two towns particularly impacted Tropical Storm Irene. The replacement manufactured home in Plainfield was also likely impacted by a flood event in 2011.

Across all of the twelve sample towns, towns are adding 3,852 of investment that requires discretionary review per year, the equivalent of about two three-bedroom homes per year. This translates to an average 321 ft^2 per town per year. The average new investment of 321 ft^2 per town per year requiring conditional review under higher-standard flood hazard regulations appears on its face to be a small amount of investment—not even a full garage-sized area per town per year.

However, when reviewed by a regional floodplain manager, analysis shows that a full discretionary review process may have deemed some of these investments nonconforming had the multi-stage permit review process been fully followed. Although it is impossible to fully determine compliance without in-person inspection, my analysis in combination with a quick desk review by a regional floodplain manager identified up to five out of 10 of these structures as possible violations of the bylaws. The other five appeared to be conforming structures as long as the base floor elevation met the local standard. Considering the 41 incidents of activity in the regulated flood hazard area, these potential violations constitute a 12% non-conformance rate. The permitting compliance analysis sheds light on how the permitting processes, or lack thereof, followed for each of the 10 discretionary review incidents either supported or failed to support

proper application of the bylaw and/or full compliance with the statewide flood hazard permitting process.

Compliance Analysis Methods

Reviewing each of the 31 incidents in the regulated flood hazard area for their levels of conformance with local bylaws narrowed the dataset down to 10 incidents in 6 towns that, based on the language of the local regulations, should have generated both a documented review process in the town records and a documented state review. Local activity on primary structures and substantial improvements that requires local discretionary review also requires State-level technical review per the Municipal and County Governments state statute (24 V.S.A. §4424 (a)(2)(D)); however, a representative of the Rivers Program confirmed that there is ambiguity in the State regulation as to whether State-level review is required for accessory structures as well. Absence of a local permit and/or of a record of State review for the 10 investment incidents would suggest that the local regulation process is breaking down somewhere between the landowner/developer and the local floodplain administrator, or the local floodplain administrator and the State. By reviewing the permits that were made available to me and by consulting local floodplain administrators and the regional floodplain managers that advise those towns, it was possible to get a picture of where those breakdowns may be occurring.

To identify whether each of the 10 incidents that should have triggered local discretionary review were indeed permitted through a local discretionary process, in late March I called or emailed each of the six Towns. I requested from the town clerk or zoning administrator permit applications submitted between 2011 and 2016 for each of the properties. Three Towns (Sharon, Troy, and West Rutland) with incidents were able to complete this request and provide digital copies of permits, if there were any. Some Towns had limited or no access to their permit databases due to the stay-at-home orders implemented across the state in March in response to the Covid-19 pandemic. Others gave no reason for their non-response.

Incidents of investment that had been permitted at the local level I then cross-checked against the State's development review database, provided to me by the Rivers Program. The limited information conveyed by local permits prompted me to request, via email, further information from three Rivers Program regional floodplain managers who serve the six towns in which discretionary projects occurred. I asked the regional managers were whether any important details in the analysis had been missed. I also asked questions about how they perceived the towns' capacity, history, and culture of flood hazard regulation enforcement (see Appendix F: Interview Questions for Regional Floodplain Managers and Town Floodplain Administrators for full list of questions). All three regional floodplain managers refused to speculate on the degree to which flood hazard regulations are critical to the Town's decision making (question 5), but generally responded to the other questions. Their responses can be seen in Table 7 and in the Discussion section.

I simultaneously contacted the floodplain administrator at five towns (Braintree, Sharon, Troy, West Rutland, and Worcester)[32] about their experience reviewing permits in the flood hazard area. I attempted to speak to administrators who served in that role between 2011 and 2016, but in some cases interviewed the current floodplain administrator instead. Four interviews were conducted over the phone, each lasting 20 to 60 minutes. The interviews were semi-structured: each of the interviewees were asked four pre-set questions (see Appendix F: Interview Questions for Regional Floodplain Managers and Town Floodplain Administrators for the full list of questions), but I also allowed conversation to range to other topics.

[32] The compliance analysis turned up incidents in seven towns that should have undergone discretionary review, but I only pursued permits that had not reached the state for review. The incident in Plainfield, therefore, was not included in the permit analysis stage.

Compliance Analysis Results

The compliance analysis identified 10 projects in the regulated flood hazard area that should have undergone local- and state-level review according to their respective towns' bylaws. Of those 10 incidents, four incidents did not go through any permitting process (see Table 6). Six applied for and were granted local permits. Of the six that were granted local permits, only three were reviewed by the State. If it is interpreted that accessory structures should have gone under State review, the data shows only a 30% compliance rate (out of the 10 incidents). If it is interpreted that State review of accessory structures is not required, then a 40% compliance rate was achieved.

Table 6. Incidents of Investment with Documented Review

Town	Character of Structure	Local Review?	State Review?
Braintree	2 non-residential structures in RV park	Y	N
Plainfield	Manufactured home	Y	Y
Sharon	Manufactured home	N	N
Sharon	Attached garage or substantial improvement and stand-alone shed	N	N
Sharon	Residence over garage	Y	Y
Sharon	Residence	Y	Y
Troy	Attached garage	Y	N
Troy	Yurt, replacing small building	N	N
West Rutland	Garage at public facility	Y	N
Worcester	Cabin (likely)	N	N
Reviews Total		6	3
Reviews as a % of Total		60%	30%

Further details about each incident are described below.

Locally and state reviewed – 3 projects

Each of these state-reviewed projects—the manufactured home in Plainfield, the residence over a garage in Sharon, and another fixed residential structure in Sharon—were replacement structures. The two residential structures in Sharon were reviewed by the state in December of 2011, four months after Tropical Storm Irene. The permits for these three projects were not requested because it was assumed that if the State found the projects to not be in violation, the conditions of the local permit decision would be in compliance with the local bylaws and the permitting process was followed as intended.

Locally reviewed, not state reviewed – 3 projects

Non-residential structures in RV park in Braintree: The Town of Braintree confirmed that there were two permits for the property but did not provide digital copies of those permits. The State has no record of communication with Braintree for this address.

Garage in Troy: An attached garage received a local permit but was not reviewed by the State. The permit, notably, did not contain a question about whether the structure is in the floodplain and neither the applicant nor the floodplain administrator indicated it as such. The structure appears to be ~25 to 30 feet above the river, suggesting that the structure may not actually be in the floodplain (unless it sits on erodible material). This suggests that either the zoning administrator did not realize the property was in the SFHA or made the decision to permit the project without State review. There was no correspondence with the State regarding this property. The floodplain manager for this region stated that for cases in which the location of the official flood lines may be in question, the State advises towns to "contact [the State] regardless of the land elevations, or at least to require a LOMA prior to permitting" (Sacha Peeler personal correspondence, May 2020).

Public facility garage in West Rutland: A new garage at the water and sewage treatment plant received a local permit in which it was recognized that this project was in a flood hazard

area. According to the current West Rutland Town Administrator, the structure is an equipment storage garage with no utilities. Under NFIP guidelines, FEMA has determined that municipal jurisdictions be regulated by the community, not by the state or federal government. A treatment plant does undergo an extensive review process by a different program within the Department of Environmental Conservation for waste and water management, and shortly after Tropical Storm Irene in 2011 the DEC did began coordinating with the Rivers Program when they authorize projects, but they don't appear to have done so for this project (Ned Swanberg phone interview, April 2020). However, it appears the permit may have been issued as far back as 1999 and the regional floodplain manager has no record of this project.

Water and wastewater treatment plants constructed using a gravity sewer system are often located in river valleys to be at the lowest elevation in town. Due to the overwhelming costs of relocating these facilities, permitting for improvement or expansion is typically issued as a variance. Environmental and safety hazard controls, then, must come through higher building code standards.

Not reviewed (no permit on file) – 4 projects

Manufactured home in Sharon: The Town has no record of a full-sized manufactured home that appears to have been replaced between 2011 and 2016. According to the Sharon listers, in February 2020 the landowner did apply to replace the current structure. The regional manager commented that the 2020 project as proposed was not in conformance with the local regulation and the applicant withdrew their application (Campbell-Broker personal communication, May 2020). This would imply that had the replacement structure identified in this study undergone similar review in the 2011-2016 period, it would likely have not been permitted. This property is right on Fay Brook Road a few miles from the center of Sharon and would have been noticeable to people driving the road.

Shed and garage in Sharon: There is no public record of these two structures and the floodplain manager working at the time does not remember them. The property is on the main road (Vermont Route 14) in the center of Sharon and would have been noticeable to people driving through Sharon.

Cabin in Worcester: This structure was erected between 2011 and 2016, a period of time when the Town government appears to not have been fully aware of the substance and implications of their higher-standard flood hazard bylaws (which includes FEHA for all reaches), did not have a floodplain zoning administrator, and did not have a floodplain zoning permit template (Ned Swanberg phone interview, April 2020). Therefore, it is possible that the residents of Worcester were unaware of an obligation to apply for a zoning permit. The cabin's location towards the back of the property likely obscures it from public view, which would mostly preclude reporting by other town residents.

Yurt in Troy: The yurt is a replacement of a former double wide or mobile home. It was a challenge to determine whether this structure was a full residence or simply a tent—the yurt appeared to be situated on a deck, but other permanent infrastructure such as electricity, plumbing, or a foundation couldn't be detected through the visual analysis methods used in this study. Whether conditional review was required depends on what the use was. As regional floodplain manager Ned Swanberg put it, "If a yurt is a tent, then the Town and State don't want to hear about it; if a yurt is a tent on a permanent structure, that is a structure" (phone interview, April 2020). Troy's zoning administrator recalls not requiring a permit likely because the building was within the footprint of the existing structure (even though the original rectangular structure was replaced by a round structure).

Results Summary

The full analysis shows that despite identifying 41 incidents of activity in the regulated flood hazard area across the twelve sample towns over a multi-year period (average 4.3 years),

only about a quarter (ten incidents) of that activity was of a nature that would require administrative discretion. The majority of the activity in regulated flood hazard areas were structure removals of structures or non-primary structures that did not require conditional review. The conformance and compliance analyses show that around five of these ten investments, such as the manufactured home in Sharon in the FEHA that did not submit a permit application and the cabin in Worcester that was built in the SFHA and FEHA, could be in violation of the local flood hazard regulations. If we are to assume that this study interpreted the land use activity correctly and all structures that did undergo some level of review were built in full compliance with the bylaw, this study finds a flood hazard area project conformance rate of at least 88% between 2011 and 2016 in the twelve sample towns.

Up to seven of the 31 new, addition, or replacement projects identified in the flood hazard area over the study period were not in compliance with the regulatory review process, depending on the interpretation of the State regulation regarding technical review of accessory structures. These seven incidents of non-compliance included all five potential incidents of nonconformance.

CHAPTER 7

DISCUSSION & FURTHER DIRECTIONS FOR STUDY

This research hopes to shed light on how much activities is occurring in flood hazard areas in towns with higher-standard regulations and how they are enforced at the local level. The study found that activity documented in the regulated flood hazard area over the study period conformed at least 88% with local bylaws. It also found each of the structures that may be non-conforming were structures that were sometimes not reviewed at the local level and were never reviewed at the State level. In three of the twelve towns, it appears as though new investments occurred without even a permit application. This suggests a breakdown in the expected relationship between town residents and town government regarding land use and flood hazard permitting. In one of these same towns, and two additional towns (totaling 3), it appears the floodplain administrator did not pass the project application to the State for review, suggesting a breakdown in the expected relationship between Town and State government. Even though local adoption of higher standards may suggest a greater level of investment in enforcing flood hazard regulations, findings suggest that the presence of higher-standard bylaws does not guarantee total conformance of projects to the regulations nor compliance with the expected regulatory process. They also confirm that nonconformance is more likely when a project has not undergone State review.

Total conformance to local bylaws is arguably not a practical expectation, but conformance rate does appear to be improved by a higher rate of compliance with the statewide legal permitting process for flood hazard regulations. So, if the State truly does place a higher value on awareness, attitude, and relationships between individuals and the multiple levels of government, then the rate of compliance with the expected permitting process is of significantly greater importance than land use conformance itself. This focuses a need for analysis not on whether there is technical competency on the part of municipalities, but on whether there is

access to information for and sufficient understanding of the regulations among the community and whether there is capacity and will to understand, apply, review, and communicate the regulations among local authorities.

Local Regulatory Context

Interviews with Rivers Program staff suggest that there are a number of elements that have to come together for zoning enforcement to work, including but not limited to: having a zoning administrator; the zoning administrator and other town entities have a good understanding of the bylaws; municipal entities such as the town highway department and building inspector who willingly comply with regulations; and access to digital bylaws and maps on the Town website. Some of these elements involve local knowledge and attitudes that was not captured by this research, but data collected on select elements that reportedly facilitate awareness and access to information (town-wide zoning, a flood map on the down website, a permit on the town website) and the capacity to regulate within the town (the town has an updated FEMA FIRM, a floodplain administrator, and mention of the floodplain or hazard area in the permit) suggest a pattern between these elements and likelihood of permitting compliance. Table 7 demonstrates that these awareness and capacity elements are not always present in the six communities where there were incidents that should have undergone discretionary review. When these fundamental components are missing, it raises questions about the capacity of municipalities to effectively enforce the flood hazard regulations they have adopted. It helps frame the discussion about the role of the state in supporting or ensuring that flood hazard standards are followed (especially when the actions do not fall under the State or FEMA's NFIP enforcement jurisdiction).

Table 7. Flood Hazard Regulation Context in Sample Towns and Incidents Reviewed for Compliance

Town	Population	Town-wide Zoning	FEMA FIRM	Flood Map On Town Website	Floodplain Admin	Permit App Online	Permit Mentions Flood Hazard	Review status
Cabot	1,322	Yes	2013 digitized	Yes	Part time zoning admin	Yes	No	--
Plainfield	1,392	Yes	2013 digitized	Yes, in bylaws	Part time zoning admin	Yes	Yes	**1: fully reviewed**
Braintree	1,105	Yes	1985 paper FIRM no elevations	Yes	Unclear	Yes	No	**1: local only**
Worcester	900	No	2013 digitized	No	Not until 2019	No (no permit at all)	--	**1: no permit**
Williston	9,341	Yes	2014 digitized	Yes	Yes	Yes	Yes	--
Vernon	2,237	No	2007 digitized	No (website has bug)	Town administrator & part time floodplain admin	No (website has bug)	--	--
Troy	2,072	Yes	1980 paper	No	V. part time zoning admin	Yes	No	**1: local only** **1: no permit**
Roxbury	734	No	2013 digitized	No	No	No	--	--
Sharon	1,413	No	2007 digitized no elevations	Yes, in bylaws	Part time floodplain admin	Yes (~2010)	By default	**1: no permit** **1: no permit** **1: fully reviewed** **1: fully reviewed**

Richford	2,458	Yes	1980 paper	No	Part time zoning admin	No	--	--
West Rutland	2,454	Yes	2008 digitized	Yes	Part time zoning admin	Yes	Yes	**1: local only**
Shaftsbury	3,487	Yes	2015 digitized	No	Part time zoning admin	Yes	No	--

Table 7 shows that towns that sent permits all the way through to state review—Sharon and Plainfield—had a floodplain administrator, flood maps and a permit accessible on the town website, and the permit had a place to indicate that the project was in a flood hazard area. Towns where projects were found to have undergone only local review had variable amounts of information and capacity, but both Troy and Braintree were missing a place in the permit to identify that the project was in the flood hazard area. In the three towns in which no permit was issued for the project, two of the towns had no town-wide zoning at all (see *Town-wide Zoning* below). It is impossible to attribute Sharon's very mixed record on permitting compliance to any particular factors based on the information available, but the lack of town-wide zoning in Sharon is the only thing that distinguishes it from compliant Plainfield in the table.

A pattern, though slight, thus emerges showing that towns that have flood regulations information available, town-wide zoning, and a zoning administrator are more likely to have projects be permitted by the town and sent to the State for review. However this pattern should be studied further, as the sample size was not large enough to draw real conclusions, and it the relationship between compliance and these elements may be more coincidental than causal (towns that are proactive about providing information and technical capacity are also proactive about regulating). Interviews with floodplain administrators shows that a number of other local dynamics may influence municipal motivation and capacity, as well as the State's ability to support municipalities in achieving zoning conformance and process compliance.

Local Regulatory Dynamics

What arose from consultation with local floodplain administrators and regional managers is that the history of flood hazard bylaw adoption, the zoning context, who fills the role of zoning/floodplain administrator, a culture of flexible, nuanced decision-making, and comfort with reporting to the State may also play a role in the dynamics of regulatory enforcement. These five themes are discussed below.

History of bylaw adoption

It is possible that a few communities in the study adopted interim river corridor bylaws in order to qualify for a higher state funding match under ERAF. If this were the case, it is thus possible to infer that towns that adopted higher standards prior to the announcement of ERAF criteria in 2012, especially those that adopted FEHA regulations, demonstrated a large degree of commitment in protecting their rivers (as described in Significance of Research subsection). Adopting higher standards necessitates alignment of the community, select board, and other players with the goals of flood hazard protection. Theoretically, these players would then also be invested in the enforcement of regulation towards the same goals.

Yet, local government officials and outspoken community players come and go. Turnover in the floodplain administrator role can lead at the very least to gaps in communication, as demonstrated by the town of Braintree, who recently had a floodplain administrator that was communicative but since that individual left, the State has had no response to its requests to contact a new administrator. On the other hand, in Worcester, a champion on the Worcester select board help get FEH regulation adopted, then the town appeared to forget about them,[33] and then another change in the composition of volunteer town government produced a new champion who about ten years later brought back to the town's attention that they had adopted FEH regulations. Therefore, the conditions under which a bylaw was adopted may not be a big factor in how bylaws are enforced. As one of the regional floodplain managers put it, "enforcement is a function of who is there when—community function, enforcing officers, et cetera" (Ned Swanberg phone interview, April 2020).

As illustrated in the case of Worcester, the role of a single actor may play a disproportionately important role in bylaw adoption and compliance. The fact that Braintree,

[33] In a 2019 visit, the regional floodplain manager discovered that Worcester Town officials were aware that they had flood hazard regulations but a) didn't know where to find them, b) had no floodplain administrator, c) had no contact for flood hazard related questions, and d) had no board of adjustments.

Worcester, and Sharon adopted FEHA bylaws suggests that someone in that community understood the science and felt comfortable with the complex bylaws, often someone with a natural resources background. This certainly bears out with the story of adoption in Sharon because it was a state-employed regional floodplain manager who was a resident of Sharon at the time who convinced the town to adopt the full flood hazard regulation package. These stories suggest the degree to which local implementation may be a function of certain individuals' conviction and comfort with flood hazard issues rather than broader community awareness and support.

Town-wide zoning

A number of interviewees suggested that the presence or absence of town-wide zoning plays a role in how residents engage with flood hazard ordinances. Neither Sharon nor Worcester has town-wide zoning. In a town with zoning, a resident would apply for a zoning permit to build, replace, or make substantial change—even if they didn't know they were in a flood hazard area—and the zoning administrator would evaluate the project for conformance to flood regulations as part of the broader permitting process. In towns without zoning, where a resident could complete a building project without a permit, the resident would have to know that they were in the FEHA or SFHA and would need to know that they were required to apply for a permit. In these cases, it is likely that lack of public awareness or barriers to information access strongly impacts how proactively residents seek the appropriate permits. This is even more true for properties in the FEHA but not in the SFHA, because property owners in the FEHA are not likely to trigger the zoning permitting process through insurance or lending activities the way ones in the SFHA might.

Zoning/floodplain administrator

As the first major stop in the permit application process, the floodplain administrator plays a powerful role in how bylaws are interpreted for any given project. As the primary contact person for flood hazard zoning questions, along with the town clerk perhaps, they also strongly influence how the science, purpose, importance, and implications flood hazard regulations are translated to the town government and the public. Who serves in this role and under what conditions they serve may also strongly influence how bylaws are communicated and enforced. Without drawing conclusions about exactly what influence they might have, I infer from interviews that diverse characteristics of floodplain administrators likely affect how flood hazard bylaws are handled from town to town: whether the administrator is volunteer or paid; whether the administrator is a community member or from out-of-town; the social, political, or occupational background of the administrator; whether the administrator has multiple roles within town government; and whether the zoning administrator has worked for other towns. The experience, expertise, time, relationships, and political will that these differences produce likely all influence the actions and decisions of a floodplain administrator. This influence is perhaps best illustrated by the comments of one interviewee, who suggested that floodplain administrators who don't have a lot of training are more nervous about using their judgment, making them less likely to permit and more likely to request State review. More expert floodplain administrators are probably more likely to be paid, residents of other towns, work only as a zoning administrator or floodplain manager, and may have prior zoning or floodplain administration experience from other towns. Paid administrators may also be Town officials with multiple roles. On the flip side, volunteer administrators are more likely to be residents of the town and new to zoning. Whether and how these factors influence the political will, degree of scrutiny administrators practice, or flexibility I could not conclude from these interviews. But if every floodplain administrator and other staffers and boards that engage in land use permitting is different, turnover of the floodplain

administrator, by consequence, would play a role in how consistently flood hazard bylaws are administered.

Flexible, nuanced decision-making

As the previous section suggests, zoning administrators use varying degrees of flexibility and discretion when making decisions. Floodplain administrators reported that they or town boards sometimes favor the permit applicant when they judge the official floodplain map to be inaccurate or the bylaws to be unclear or unreasonable, or may rule counter to the State's opinion if the project falls in a gray area. One floodplain administrator felt experienced enough to be confident to interpret the bylaws without or against the State. Another reported that although they never permit in the floodway and always seek the advice of the State if the project is high-risk, they often dedicate time to the application to verify if the project is indeed in a flood hazard area and encourage applicants to go for LOMAs if not. One of the floodplain administrators interviewed relayed that they let their floodplain manager certification lapse because they got "too down" about by their experience administering floodplain regulations after watching a number of property owners forced to abandon their requests to rebuild after Tropical Storm Irene. This particular quote highlights just how difficult it is to arbitrate between flood hazard protection and rights to property—and livelihood. While the study found no indication that any towns permitted replacement primary structures in areas where floods had damaged the existing structure without the State's approval, the tension between flood risk reduction and private property rights is apparent in these towns in both high- and low-risk flood hazard areas.

Reporting to the State

As alluded to above, some floodplain administrators consciously choose to not send conditional permit applications to the State for review. One floodplain administrator stated that they "usually" do not contact the state, though it was unclear whether they knew that they are

obligated to do so for certain structure types. One floodplain administrator shared that they found their regional floodplain administrator quick to respond to their communications, but another explained that it takes a lot of time to prepare the full list of required documents so the State can do a quick desk review, and as a result the administrator would never ask a volunteer board member to prepare those documents. This latter comment suggests that the process of preparing a permit for State review is burdensome and may be a barrier to meeting the requirement that permits be submitted for State review. It isn't hard to imagine that a very part time zoning administrator with a full-time job who gets paid $30 per permit may not be as likely to prepare permits for State review on a regular basis compared to a part-time administrator that is in the office weekly and does the same work for multiple towns.

These dynamics show that although the community's awareness of the regulations, their ability to access information related to flood hazard zoning, and the capacity of the Town to regulate are all important, the idiosyncratic presence of "champions" of the regulation within the community, the administrator's background and terms of employment, the transitory nature of local authorities, and individual discretion also play a crucial role in how the regulations get applied locally. Elements that are so closely linked to the individual are not as easy to influence through technical support as the more operational elements are. It thus becomes obvious that the structure of mandates, incentives, and penalties in a compliance model play an important role in the success of shared governance of local flood hazard mitigation.

Possible Directions for the State's Role

The findings show both the success and the limits of decentralized permitting in areas with a number of Vermont municipalities. This research shows that better compliance with the permitting process at the local level (i.e. the property owner applies for a permit, the town thoroughly reviews the permit application, and the town sends the permit application to the State for review) increases conformance of new, replaced, or modified structures to the local higher-

standard flood hazard regulations. Making sure investment in the flood hazard area complies with flood hazard permitting regulations in Vermont relies on a number of voluntary actions: the willingness of a landowner to submit a permit; the willingness of a floodplain manager to enforce the bylaws; the willingness to send permit applications to the State for review (and the willingness to follow their recommendations); and the willingness of a community to stay engaged with regulations and keep neighbors compliant. This web of voluntary actions are often taken by communities in the face of a lack of resources and prior technical expertise, an incentive system that stops at adoption (i.e., does not incentivize enforcement per se), a lack of triggers for submitting permits (in some cases), and barriers to sending permits to the State for review. The local floodplain administrators who carry the most responsibility for ensuring that flood hazard activity undergoes the appropriate review embody a range of experience and interests, and sometimes have to navigate regulating in a community where understanding and support for the regulations and their purpose waxes and wanes. It is clear that to balance the conflicting goals and rights of a community and its members, zoning administrators often rely on their own discretion for interpreting bylaws.

The policy question thus becomes, how willing is the State to tolerate inconsistent conformance among towns, given the constraints that communities face and given the seeming importance of local control? Or on the flip side, how many resources is the State willing to spend to increase compliance and by how much could they truly increase it? To explore the general question, let us imagine the State takes extreme action and regulates the river corridor[34] via a statewide law such as Act 250.

Greater State control over flood hazard zoning would bring statewide higher-standard flood hazard regulation in Vermont, instead of the patchwork of enforcement that characterizes

[34] I use the river corridor and not the flood hazard area as a whole because I am not sure whether state control of FEMA-designated flood hazard areas would conflict with federal law.

the present situation. State control would bring a universal standard for flood hazard mitigation, and expert, uniform application of those standards. The State would be able to shift its attention and resources from constantly training and supporting hundreds of towns in being effective regulators to doing effective regulation themselves.

However, the findings of this study may suggest that a stronger role for the State in regulation may not result in significantly less encroachment into the flood hazard area. For one, when communities choose to adopt regulations they have entered into a kind of agreement between themselves that helps, as the Association of State Floodplain Managers (2008) suggest in their No Adverse Impact paper, to foster community accountability. As a community-level agreement, both property owners and local authorities may be more likely to strive to meet the agreed upon standards. Second, the fact that up to three out of ten property owners did not apply for a required permit suggests that there is a certain level of noncompliance stemming from community member (in)action that the State might not fare any better with than the municipality does. Without eyes on the ground, enforcement will still rely on local administrators to notice changes that have not been reviewed. Furthermore, even if a property owner did know they ought to apply for a permit, having to consult or apply through the State could be more of a deterrent than having to communicate with the Town. Third, though the State may be able to more reliably provide the public access to flood hazard maps, regulations, and other resources than communities, the importance of key community members for information dissemination cannot be ignored. Clearly, the tradeoffs between greater State control and greater local control are complex.

The State is now asking communities who wish to qualify for the highest level of state aid under ERAF to adopt or go beyond the higher standards outlined in the 2018 model flood hazard bylaws. While flood hazard regulations are still a community's choice, this new requirement shifts the adoption compliance model from one that allows for more community discretion in how flood hazard mitigation is reached to one where content is more standardized.

There is one obvious benefit to this change with regard to enforcement: it incentivizes towns that currently regulate only the FEHA to instead regulate all of the river corridor. River corridor zoning is easier for communities to understand and be responsive to because the maps are available through the State's online Flood Ready Atlas. On the other hand, it will be interesting to see whether giving communities less flexibility in what standards they apply will influence their willingness to adopt and to enforce flood hazard regulations, given the assumptions already described about the value of community agreement. Most importantly though, the literature on cooperative compliance asserts that the model works best when the people and communities being regulated believe there are real consequences to non-compliance at the level of regulation implementation (Monday et al. 2006). The new ERAF criteria, like the old, do not introduce any mechanism for sanctioning or punishing failure to enforce.

Adoption and enforcement of flood hazard regulations is not just highly dependent on individuals—a "champion" that brings the town government and community on board or the individual(s) who enforce the standards—but also to the fact that better compliance with permitting appears to correlate with better conformance of structures to flood regulations. If one of the major issues with consistent local compliance is the constant change of flood regulations administrators, then what are the ways to shift away from a reliance on "champions" and onto fostering expectation and capacity—perhaps the "culture" that the Rivers Program leaders talk about—among the community and town government as a whole? The answer may lie in strengthening the cooperative enforcement model and as a component of that model, using myriad strategies to strengthen state-town relationships. Though political pressure may always be too strong for true cooperative enforcement, and economic pressure may certainly always maintain influence over local decisions, if the community and Town government develops a cultural expectation to always consult a higher authority, the power of a single individual to hamper full review or loosely interpret bylaws is diminished.

The ERAF incentive program, which encourages bylaw adoption, and community assistance, broadly speaking, are the State of Vermont's two primary strategies for getting Vermont towns to properly implement flood hazards regulations. Without defined goals for conformance rate and without generalized conformance and compliance data, it is difficult to evaluate how this compliance model could become more effective. But a few apparent limitations with the model provide opportunities to think about improvements. What Vermont's compliance model currently lacks that effective cooperative enforcement models share is a credible threat of penalty. If there was a consequence for lax higher-standard flood regulation enforcement, what could the penalty to the town be? The State's orientation toward changing attitudes and communication as goals rather than achieving a set rate of compliance may mean flexibility, discretion, and the building of long-term relationships should remain the central focus of Vermont's compliance model. The State already acknowledges that there are geographic areas where the regional floodplain managers need to improve floodplain management awareness. For example, the last Community Assistance Visit from the State or FEMA to the town of Troy was in 1997. Communities that go above and beyond minimum NFIP standards may need a proportional increase in support for implementing and enforcing those higher standards. The State would therefore want to ask itself: How can the Rivers Program continue to build the kinds of long-term relationships with communities that make cooperative enforcement models work with very little use of penalty, especially given the low ratio of State staff to communities and the high rate of turnover in town administration? If floodplain managers exercise a high-level of discretion in their permitting practices, how can state floodplain managers build their trust in local discretion? And if some of the breakdown in compliance with flood hazard regulations comes down to public awareness and access to information, how can the State direct resources toward making information more easily accessible?

Based on the findings above, if the State choses to not pursue greater control over local flood hazard regulation, it potentially could instead focus on the following:

1) Foster stronger relationships with communities:
    a) Increase staffer to community ratio
    b) Conduct more community visits and trainings
    c) Create and distribute a flood regulations enforcement manual that describes how to foster voluntary compliance, resolve issues, and how to take enforcement action
    d) Help regional planning agencies strengthen their capacity to serve as a resource to towns
    e) Reduce the barriers to preparing permit for State review
2) Continue to support the buyout program to mitigate fights and resentment over property loss
3) Create more options for regulatory sticks:
    a) Redesign ERAF criteria to include a mechanism for being sanctioned or penalized for failing to enforce local bylaws (i.e., reduction in assistance %). Criteria could be that a town must have a floodplain manager that the state can contact, must publish floodplain maps and contact number for the floodplain manager, or must send all conditional permits to the state for review.
    b) Establish a system for monitoring compliance
4) Clarify the rule regarding whether local permit applications for accessory structures have to be reviewed by the State

While recognizing that all of these strategies require additional funds that the State may not have, there appears to be a number of options for strengthening communities' cooperative compliance with flood hazard regulations. More research is needed to dive deeper into actors, attitudes, resources, communication, and land use outcomes to continue to identify effective and viable policy solutions.

Further Directions for Study

Although the Rivers Program identified attitudes and expectations rather than statistical thresholds in their goals for statewide flood hazard mitigation, measurement of the rate of flood

hazard regulation compliance over time could prove a good proxy for attitudinal change. The complexity of analyzing and interpreting compliance with town flood hazard bylaws that do not follow the State's model flood hazard bylaws verbatim has been well documented in this paper. However, an expanded and streamlined study may be feasible in a few years and could add greatly to the state's understanding of the impact of bylaws on investment. Such a study would require a visual layer, ortho-imagery if 2-D surface change were to be included or LiDAR if not, captured in 2021 or later to create a 5-year analysis span starting with 2016 data. Thirteen towns with updated river corridor bylaws could be used in a study that begins in 2016. Later study time frames could include larger samples. Visual analysis of every reach in a municipality takes a long time, so doing this type of study on a large and/or statistically significant sample would be extremely time consuming. Regardless, follow up study over a greater period of time would generate a better understanding of the track record and capacity for regulating flood hazards in Vermont towns.

In addition to expanding this study, a number of additional lines of inquiry could be pursued:

- Assessment of local planning board/design review board/zoning board of appeals notes and interviews with actors to better understand permitting rationale and what kinds of conditions are applied.
- Regression analysis of the factors that the literature and the State has identified contribute to local awareness and capacity, such as whether there is a floodplain administrator, whether they are volunteer or paid, the rate of turnover, how well bylaws are understood, whether maps and bylaws are accessible to the public, etc., against dependent variables such as the proportion of permit applications the town sends to the state or how much development is happening in the regulated area (Ned Swanberg phone interview, April 2020); this would require a larger n of appropriate towns

- Analysis of the relationship between the physical and social cost of Irene and practices of enforcement and compliance.
- A survey of floodplain administrators asking when and why they refer projects to the state, and how they perceive their relationship to the state.
- A longitudinal study that attempts to measure a possible cultural shift toward "aversion" to flood hazard development, perhaps through surveys or focus groups of developers, real estate agents, and floodplain administrators.
- There is evidence from this study that the variation between how seriously towns take their bylaws comes town to individuals. A study of town officials that captures the relationship between passion and outcomes may further elucidate the significance of individual actors at different town-size scales and provide insight on how to work with them.
- Comparison of encroachment in the constrained versus unconstrained river corridors, which are currently being mapped and classified by the State's Functioning Floodplains Initiative. According to the Rivers Program, development in unconstrained corridor is of greater concern in flood hazard mitigation (Kline and Evans 2019).
- Research into the existence of alternative natural resource protection or hazard mitigation compliance models that utilize stronger enforcement mechanisms (e.g. wetlands). This research should look at all 49 other states but also for international examples.
- Case studies of municipalities that successfully enforce flood hazard regulations without town-wide zoning
- A study of property owners subject to river corridor regulations from different states that utilize different protocols for assessing the river corridor to understand whether the accuracy of mapping protocol or how protocol is communicated could be a factor for the level of deference that municipalities and developers show the regulation.

CHAPTER 8

CONCLUSION

A fundamental goal of Vermont's flood hazard mitigation community is to minimize flood damage in Vermont. The realization of this goal rests, almost entirely, with individuals and local governments. The shared governance of flood hazard mitigation, between federal, state, and local governments, is both empowering to communities and low cost to the State and federal government. Yet it means that the implementation of complex and technical hazard regulations relies on local officials and community members who comply voluntarily, whose actions are not readily visible to the State, and who have numerous constraints and competing priorities.

This study of twelve Vermont towns found in those towns a fairly high degree of conformance to local regulations but a mixed record on compliance with the State's expectations for the permitting process. There was on average a little under one investment per town over a 4.3-year period that was significant enough to trigger a conditional permit review. Further analysis of these projects demonstrated that within the study sample, activity in the regulated flood hazard zone conformed to local bylaws at a rate of about 88%. Only three of the ten projects that triggered conditional review were reviewed at the State level, as is the expectation for new, replacement, or improved structures, and the fact that none of the suspected non-conforming structures received a State-level review (and some missed local review) suggests that receiving full review, regardless of local authorities' exercise of discretion, will increase the rate of conformance. However, towns in the study only had higher-flood hazard regulations, or flood regulations at all, for a very short time before this study analyzed them for zoning conformance. And without past compliance data or quantified goals to compare with, it was not possible to make a value statement about how well towns are carrying out their duties in regulating flood hazard areas or whether their effectiveness is changing over time.

The stated goal of the Vermont Rivers program leadership is to erode away the attitude in Vermont that it is okay to invest in the flood hazard area. While the State cannot control the daily actions of Vermonters or Vermont's hundreds of municipal governments, it does retain some control over how awareness is spread among the public and those governments, how municipal-state relationships evolve, and how the incentives used to promote cooperation with reflexive laws are structured. It is up to the State to determine whether greater state control or stronger consequences are worth the tradeoffs. Had the State provided a set measure for how much compliance they expected out of communities, greater State control might be an obvious policy direction to explore. But the Rivers Program is asking for a cultural shift at the local level, and cultural shifts take time.

More than one local floodplain administrator expressed the sentiment that Vermont towns on the whole are getting more serious about flood hazard management. As one interviewee put it: "In some states, floodplain offices are on the landowner's side—helping them get as much built in floodplain as possible. This is not Vermont. There was a long history in Vermont of towns adopting flood regulations and ignoring them. This is less true now." This may be less true now because the threat of flood hazards has become very real in Vermont in the last three decades. Every new flood disaster forces communities to be more aware of the risks they face from accelerating climate change and increasing flood hazard. Every new flood disaster forces communities to stop ignoring their flood regulations. And every new disaster provides Vermont communities the opportunity to reassess what a meaningful balance between do-no-public-harm and private rights looks like for a community, and to connect with the State over shared goals. But if the State would like to encourage communities to do these things before the next major disaster, they have to keep evolving their approach to encouraging community compliance. The State of Vermont has a high bar for towns in how they should "support the variety of ways in which rivers function" and keep their residents and public assets safe. These communities will need to be continued to be evaluated for whether they are indeed and how they can be supported

in shifting toward greater deference to the river and its destructive power through adoption and enforcement of the State's higher standards.

APPENDIX A

VERMONT MODEL FLOOD HAZARD BYLAWS - HIGHER STANDARDS CROSS-WALK

https://dec.vermont.gov/watershed/rivers/river-corridor-and-floodplain-protection/municipal-assistance

Federal (NFIP) Minimum Requirement	Model Bylaw Higher Standard	Rationale
A building's lowest floor must be elevated equal to or above the base flood elevation (BFE). (44 CFR, 60.3(c)(2) and (3))	A building's lowest floor must be elevated at least **2 feet above the base flood elevation** (model bylaw Section E.IV.C.12.a)	Elevation to the BFE does not provide adequate protection due to outdated federal flood studies that do not account for increased watershed development or future conditions hydrology, and larger flood events. Additional elevation (a.k.a. *freeboard*) is relatively inexpensive to build into development, and typically pays for itself in reduced flood insurance premiums and prevented flood damage within the first 10 years of a structure's lifetime.
In lieu of elevation a non-residential building may be dry floodproofed to the base flood elevation. (44 CFR, 60.3(c)(3))	In lieu of elevation, a non-residential building may be dry floodproofed to at least **2 feet above the base flood elevation** (model bylaw Section E.IV.C.12.b)	Dry floodproofing to the BFE does not provide adequate protection due to outdated federal flood studies that do not account for increased watershed development or future conditions hydrology, and larger flood events.
Absence of a standard regarding flood storage capacity: Filling and construction may occur in the flood fringe (outside the floodway) without considering loss of flood storage volume.	Above grade development is required to meet the compensatory storage requirement to ensure **no net loss of flood storage volume** (model bylaw Section E.IV.B.1)	A major shortcoming of the NFIP is that the standards are focused on reducing flood inundation risk to new development, but do not consider the cumulative degradation of floodplain resources and increased flood hazards to existing development that result over time due to continued encroachment and filling of floodplains.
Encroachments in the floodway are prohibited unless an engineer can certify that there will be no increase in base flood elevation (44 CFR, 60.3(d)(3))	Encroachments in the floodway are prohibited unless an engineer can certify that there will be **no increase in** base flood elevation or **velocity** (model bylaw Section E.IV.A.2)	Vermont's mountainous terrain means we have higher gradient streams and thus, higher velocity floods. Along many reaches of river, encroachment in the floodway will not increase the water surface elevation, but instead will increase the velocity of the floodwaters. It is important to also consider velocity to ensure that there is no adverse impact to adjacent and downstream properties and infrastructure.
Absence of a standard regarding critical facilities.	**New critical facilities are prohibited** in the Flood Hazard Area (model bylaw Section E.III.D.1.b).	Facilities which provide critical services (e.g. police, fire, hospital), or services that are depended on during and after disasters (public utilities and infrastructure) should be protected to an even higher standard than other development. Failure to either avoid flood hazard areas or

Federal (NFIP) Minimum Requirement	Model Bylaw Higher Standard	Rationale
	Existing critical facilities to be replaced or substantially improved shall be constructed so that the lowest floor, including basement, **shall be elevated or dry-floodproofed at least one foot above the elevation of the 0.2% annual flood height (500-year floodplain), or three feet above base flood elevation, whichever is higher.** (model bylaw section E.IV.C.12.d)	provide flood protection to critical facilities creates severe and unacceptable public safety risk.
Absence of a method and standard to manage for flood-related riverine erosion	**Adoption of the ANR-mapped River Corridors and prohibition of new development in open/undeveloped river corridors.** Exceptions allow infill and redevelopment in areas that are already densely developed (model bylaw Section D)	NFIP flood hazard area maps only depict flood inundation risk and do not characterize areas at risk from flood-related erosion. 44 CFR 60.5 and 24 V.S.A. § 4424 provide a mechanism for communities to regulate for erosion hazards but are not mandatory. Adoption/regulation of river corridor standards helps communities achieve greater flood resilience and maximize state flood recovery funding under ERAF.
Absence of an explicit standard regarding storage and junk yards in the floodway	Prohibition of storage and junkyards in the floodway (model bylaw Section E.III.D.2.d)	With engineering certification of no increase in base flood elevation, the minimum standard does not prohibit the storage of materials and junkyards in the floodway, where floodwaters are typically fast and deep, thus increasing the risk that these materials get mobilized during a flood.
Substantial Improvements to existing buildings must be brought into compliance with the floodplain management regulations (44 CFR, 60.3(c))	Requires improvements to be **tracked cumulatively over a 3-year** period to ensure that flood regulations are triggered given enough reinvestment in the building (model bylaw Section B – *Substantial Improvement* definition)	The minimum standard has an inherent loophole that undermines the intent. The intent is to ensure that structures are mitigated once a certain level of additional investment goes into improving the building (50% or more of the buildings market value). Without a specified timeframe, owners avoid triggering the regulations by doing multiple projects, each under the 50% threshold.
Absence of a Certificate of Occupancy requirement	Requires a Certificate of Occupancy (model bylaw Section C.III.C)	Violations may arise long after the project is complete because many communities do not verify that the project was built as proposed and permitted. The Certificate of Occupancy provides a tool to the community to ensure compliance with the provisions of the permit.
The NFIP provides relief to historic structures by giving communities the	If a historic structure is substantially damaged or being substantially improved, improvements	Requiring improvements to historic structures to meet "mitigation performance standards" helps to ensure that

Federal (NFIP) Minimum Requirement	Model Bylaw Higher Standard	Rationale
option to either exempt them from the substantial improvement calculations (via definition), or by using variance provisions as a means to provide relief to historic buildings.	must comply with "mitigation performance standards" (model bylaw section E.IV.C12.e)	such buildings are able to better withstand future flood events and reduces public safety concerns, while still maintaining their designation as an historic structure. Additionally, implementation of mitigation performance measures may help to lower flood insurance premiums since the subsidies for historic structures are being been phased out.
New, substantially improved, or replacement manufactured homes in a pre-FIRM portion of a manufactured home park must be elevated to either the BFE or to 36 inches in height above grade (44 CFR 60.3(c)(12))	Treats manufactured homes the same as conventional housing. The lowest floor of a new, replacement, or substantially improved manufactured home must be elevated at least 2 **feet above the base flood elevation** (model bylaw Section E.IV.C.12.a)	For the same reasons that the model requires conventional housing elevated 2 feet above BFE, manufactured homes are included in this category. An assessment of pre-FIRM mobile home parks can help to determine if the community wants to consider relaxing the elevation requirement. If the community is considering this provision, DEC would recommend that the manufactured home is elevated at least 48-56 inches in height above grade.
Absence of a requirement to provide dry land access	Requires Subdivisions and Planned Unit Developments to be accessible by dry land access outside of the flood hazard area (model bylaw section E.IV.C.11).	Requiring dry land access provides safe egress for property owners and reduces risk to first responders that may need to access development during a flood emergency.

The above constitute the significant higher standards in the model bylaws. In many cases, the model adds specificity, not higher standards per se, since the NFIP minimum standards are silent with respect to many aspects of development that communities must regulate in federally-mapped flood hazard areas. The full text of the federal minimums a community must adopt to be compliant with the NFIP are found in Title 44 of the Code of Federal Regulations, Part 60.3: https://www.ecfr.gov/cgi-bin/text-idx?SID=768f4e857e402da788e29adf6bae24f6&mc=true&node=se44.1.60_13&rgn=div8

Communities may adopt the federal minimum standards of the NFIP and achieve access to federal flood insurance and be eligible for FEMA hazard mitigation grants. However, adoption of federal minimums is discouraged since these standards will result in increased flood hazard risk over time. In addition, adoption of federal minimums makes communities less competitive for federal hazard mitigation funding.

APPENDIX B

TOWNS EXCLUDED FROM SAMPLE

Town	Interim RC adoption date	Population (2010 census)	Reason for not including
Bradford	2014 (amended)	2,729	Imagery span <3 years
Windham	3/9/2009	382	Population <500
Orwell	4/3/2009	1,347	Bylaws unsatisfactory
Baltimore	8/9/2009	282	Population <500
Peru	5/19/2010	329	Population <500
Bolton	7/19/2010	1,353	Bylaws unsatisfactory
Lincoln	3/1/2011	1,340	Bylaws unsatisfactory
Rupert	8/23/2011	646	Population <500
Thetford	9/26/2011	2,564	Imagery span <3 years
Winhall	12/7/2011	589	Population <500
Granby	12/27/2011	103	Population <500
Readsboro	1/12/2012	727	Bylaws unsatisfactory
Essex	1/24/2012	10,132	Imagery span <3 years
Stowe	6/25/2012	4,406	Imagery span <3 years
Barnard	11/6/2012	760	Imagery span <3 years
North Bennington	3/4/2013	1,685	Bylaws unsatisfactory
Plymouth	5/20/2013	494	Population <500
Guildhall	8/19/2013	185	Population <500
Warren	11/12/2013	1,716	Bylaws unsatisfactory

APPENDIX C

BYLAW ANALYSIS

Town	Bylaw changes within study period	Town has zoning?	Bylaw adoption date	Spatial application of fluvial erosion hazard regulaton		FEHA (if different from other ar	
				Areas of application	*Designated reaches*	*Improvements to existing primary structures*	*Accessory structures <500 sqft*
Key: *X = prohibited* *P = permitted* *C = conditional* *A = exempt* *O = no mention*							
MODEL BYLAWS						**C**	**C**
Braintree		Yes	03/04/10	FEHA* & SFHA	Ayers Brook	C	C
Cabot	2010 vs. 2013	Yes	02/10/10	SFHA		N/A	N/A
Plainfield		Yes	03/02/10	SFHA		N/A	N/A
Richford	2010 vs. 2012	Yes	07/01/10	SFHA		N/A	N/A
Roxbury		Not enacted	07/02/05	SFHA		N/A	N/A
Shaftsbury		Yes	08/06/12	SFHA		N/A	N/A
Sharon		No	12/06/10	FEHA & SFHA**	Broad, Elmers, Fay, Quation; 50 feet of Broad, Mitchell, High Pole Branch	C	C
Troy		Yes	10/18/10	SFHA		N/A	N/A
Vernon		No	09/27/10	SFHA		N/A	N/A
West Rutland		Yes	06/11/12	SFHA		N/A	N/A
Williston		Yes	2019***	SFHA		N/A	N/A
Worcester		No	03/14/10	FEHA & SFHA	All reaches	C	C

*FEHA = Fluvial/Flood Erosion Hazard Area
** and lands near streams that may be at risk from flooding or erosion but that have not been mapped
*** Earlier version not found, but river program believes the language is unchanged

reas)			Floodway (if different from other areas)				Permitting conditions (in all areas unless otherwise noted)	
Accessory structures >500 sqft	*Building utilities*	*At grading parking for existing buildings*	*Accessory structures*	*At grade parking for existing structures*	*Improvement to existing structures*	*Improvement to existing roads or drainage*	*New structures*	*Storage/junk yards*
X	**C**	**C**	**X**	**C**	**C**	**C**	**X**	**X**
X	C	C	X	C	C	O	X	X
N/A	N/A	N/A	X	C	C	O	X	X
N/A	N/A	N/A	X	X	C	O	X	X
N/A	N/A	N/A	X	O	C	C	X	X
N/A	N/A	N/A	X	C	C	O	X	X
N/A	N/A	N/A	X	O	C	O	X	X
X	C	C	X	C	C	O	X	X
N/A	N/A	N/A	X	O	C	O	X	X
N/A	N/A	N/A	X	O	O	O	P (except in	P (except in
N/A	N/A	N/A	X	C	C	O	X	X
N/A	N/A	N/A	X	O	C	O	X	X
X	C	C	X	C	C	O	X	X

Substantial improvement /relocation/floodproofing of existing structures	*Non-substantial improvement*	*Accessory structures >500 sqft*	*At grade parking for existing structures*	*On-site water or septic systems*	*Fill as needed to elevate existing structures*	*New fill (except when elevating structures to BFE)*	*Grading, excavation, creation of a pond*	*Road/Stormwater infr. maintenance*	*Road (existing) improvement*
C	**P**	**C**	**C**	**C**	**C**	**X**	**C**	**A**	**C**
C	P (C in fldwy and FEHA)	P (C in fldwy and FEHA)	P (C in floodway or FEHA)	C	C	X	C	A	C
P (C in fldy)	P (C in fldwy)	P (X in fldwy)	P (C in fldwy)	P (C in fldwy)	C	X	C	A	C
C	P?	P (X in fldwy)	P (C in	C	C	X	C	A	C
C (X in fldwy)	P (C in fldwy)	C (X in fldwy)	O	O	C	X	C	P	P (C in fldwy)
C	P?	P (X in fldwy)	P (C in	C	C	X	C	A	C
C	P (C in fldwy)	P (X in fldwy)	P	P	O	X	C	O	C
C	P (C in fldwy and FEHA)	P (X in fldwy, C in FEHA)	P (C in fldwy and FEHA)	C	C	X	C	A	C
C	P	C (X in fldwy)	O	P	O	X	C	A	C
P	P	P	P	P	O	O	O	O	O
C	P (C in fldwy)	P (X in fldwy)	P (C in floodway)	P/C (C in fldwy)	C	X	C	A	C
C	C	C	O	O	O	O	O	A	O
C	P (C in fldwy and FEHA)	P (X in fldwy; C in FEH)	P (C in fldwy and FEH)	C	C	X	C	A	C

Road infr./public projects dependent on stream access/crossing	*Channel Management*	*Recreation Vehicles*	*Recreation*	*Open Space*	*Forestry in good practice*	*Agriculture in good practice*	*Critical facilities*	*All development not exempted, permitted, conditionally approved*	*New/replacement storage tanks for existing structures*
C	**C**	**P**	**A**	**A**	**A**	**A**	**X**	**X**	**C**
C	O	P	C	A	A	A	O	O	C
C	C	P	A	A	A	A	X	X	C
C	O	P	A	A	A	A	X	X	C
P (correctly sized bridges	O	O	C	O	O	O	X	X	O
C	C	P	A	A	A	A	X	X	C
C	O	P	O	O	O	O	X	X	C
C	C	P	A	A	A	A	X	X	C
C	C	P	O	O	A	A	X	X	C
O	C	P	O	O	O	O	O	O	O
C	C	P (outside fldwy)	A	A	A	A	X	X	C
O	O	P (outside	O	O	O	O	O	O	O
C	C	P	A	A	A	A	X	X	C

Public Utilities	*Building utilities*	*Removal of building in whole or part*	*Public projects which are functionally dependent on stream access or stream crossing*	*Storage for floatable/haz ard/toxic materials*	*Floodwalls*	*Quarrying, gravel and mineral extraction*
C	**X**	**A**	**O**	**O**	**O**	**O**
C	P (outside FEHA and fldwy)	O	O	O	O	C
C	P	A	O	O	O	O
C	P	A	O	O	O	O
P	O	O	P (outside fldwy)	X	P (outside fldwy)	O
C	P	A	O	O	O	O
C	P	O	O	X	O	O
C	P (outside fldwy and FEHA)	A	O	O	O	O
C	P	A	C	O	O	O
O	O	O	O	O	O	O
C	P (outside fldwy	A	C	O	O	O
O	O	O	O	O	O	O
C	P	A	O		O	O

APPENDIX D

VISUAL ANALYSIS DATA SOURCES

Data layer	Description	Source	Quality
Aerial imagery NAIP	Geo-referenced orthoimagery "leaf-on" RGB and near-infrared	NAIP via Vermont Open Geodata Portal	2011: 1 m resolution 2016: 0.6 m resolution; false color (IR band) and Normalized Difference Vegetation Index layers
Elevation LiDAR	Statewide nDSMs collected between 2013 and 2017	VCGI LiDAR Program via Vermont Open Geodata Portal	0.7 m resolution
Town boundary VT Data – Boundaries, All Lines	Vermont villages, towns, counties	Vermont Open Geodata Portal	Good
Rivers and streams VT Hydrography Dataset – cartographic extract polygons	Interconnected and unique identified stream segments or reaches that make up surface water drainage system	National Hydrography Dataset via Vermont Open Geodata Portal	Good
River Corridor River Corridors (August 27, 2019)	Geomorphic assessment of watersheds over 2 sq. miles developed using map-based data on watershed catchments, stream gradient, reference channel width, meander belt widths, valley walls, and major transportation features	Vermont Open Geodata Portal	Good May have been modified since study time period Is not equivalent to FEHA
SFHA vtflood_SFHA	Composite layer of official FEMA dFIRMs, unofficial digitized FIRMs, and amendments	VCGI via Ned Swanberg (Rivers Program)	Incomplete and unofficial dataset, but best digital layer available May have been modified since study time period
Floodway Floodway_extract	Extracted from above	VCGI via Ned Swanberg (Rivers Program)	Incomplete and unofficial dataset, but best digital layer available May have been modified since study time period

APPENDIX E

CODING PROTOCOL

1. GIS (FID)
2. GIS object ID (OBJECTID)
3. ID code (Id)

Order in which incidents were recorded by Tamsin

4. Town name (Town)
5. Type (Type)
    a. Structure -> STRUCT
    b. Driveway -> DRIVE
    c. Renewable energy -> RENEW
    d. Cut -> CUT
    e. Fill -> FILL
6. Sub-type of incident (SubType)
    a. Manufactured/mobile home -> MANUFACT
    b. Driveway -> DRIVEWAY
    c. Single family home -> SINGLE
    d. Non-residential building -> NON-RES
    e. Ground-mounted solar -> SOLAR
7. Zone (Zone)
    a. zoned for RC, RC & SFHA -> A
    b. zoned for RC, RC outside/bordering SFHA -> B
    c. zoned for RC, RC (SFHA unknown) -> C
    d. zoned for RC, SFHA (outside or no RC delineation) -> D
    e. not zoned for RC, RC & SFHA -> E
    f. not zoned for RC, RC outside/bordering SFHA -> F
    g. not zoned for RC, RC (SFHA unknown) -> G
    h. not zoned for RC, SFHA (not RC) -> H
8. Notes
9. Tamsin's observations of structure
    a. Investment (addition) or removal (AddRemove)
    b. Investment -> ADD
    c. Removal -> REMOVE
    d. Replacement -> REPLACE
10. Coordinates (X,Y)
11. Waterway (Waterway)
    If no name given, named as tributary to
12. Shape length (Shape_Length)
    GIS generated

13. Incident size in SF (Shape_Area)
    Calculated as ft^2
14. State has reviewed (State_Revi)
    From state 2011-2017 development review database
    a. Yes -> Y
    b. No -> N
15. State review notes (State_Re_1)

From state 2011-2017 development review database

16. Address (Address)
17. LOMA (LOMA_)
    a. Yes -> Y
    b. No ->N
18. Town has designated town center (DesTownCtr)
    a. Designated town center -> Y
    b. No designated town center -> N
19. Setting (DesTownCen)
    a. In town center or smart growth overlay -> Y
    b. Not in town center or smart growth overlay -> N
20. Distance from village core (DistCore)
21. State's review notes

Can be N/A

22. Available flood data (AvailFlood)
    a. None -> N
    b. SFHA only -> S
    c. SFHA incomplete -> SI
    d. Floodway only -> F
    e. SFHA and floodway -> SF
23. Years of analysis (Years)

# of years analysis spans (AnalSpan)

24. Bylaw compliance determination (Compliance)
    a. Prohibited -> X
    b. Permitted -> P
    c. Conditional Use -> C
    d. Exempt -> A
    e. No mention -> O
25. Bylaw category under review (BylawField)
    a. New structure -> new structure
    b. Replacement structure -> replacement structure
    c. Accessory structure > 500 ft -> accessory structure > 500 ft
    d. Improvement > 500 ft -> substantial improvement
    e. Driveway -> at-grade parking
    f. Ground-mounted solar -> solar array
26. Notes on compliance with bylaws (BylawNote)
    Reasons for interpretation

27. Was a permit application submitted to Town (PermitApp)
    a. Yes -> Y
    b. No -> N
    c. Unknown -> U
    d. Decision made by reviewing board (Decision)

APPENDIX F

INTERVIEW QUESTIONS FOR REGIONAL FLOODPLAIN MANAGERS AND TOWN FLOODPLAIN ADMINISTRATORS

Regional Floodplain Managers

1) Even though there is nothing noted in the database for these properties between 2011 and 2016/2017, do you have any memory or anything on file indicating that the Town contacted you seeking assistance with these sites in this time period?

2) If no to question (1), is it your assessment that the Town should have sent these permit applications to you/the state for review?

3) Are there any nuances to the flood mapping or flood hazard regulations of this town, that I haven't yet identified, that could explain how these permits might have been approved without discretionary review by the review board and without being passed to the state for review?

4) In a few sentences, how would you characterize the capacity, history, and/or culture of flood hazard zoning enforcement in the town?

5) In your experience with officials and projects in this town, with respect to the decision to permit development in the flood hazard area, which of the following statements feels the most true (please choose only one):

(A) Flood hazard regs are critical to the Town's decision-making

(B) Flood hazard regs are important to decision-making, but the Town takes into consideration other factors

If B), what other factors?

(C) Flood hazard regs are moderately important to decision-making, but the Town mostly considers other factors

If C), what other factors?

(D) Flood hazard regs are not very important to the town's decision-making

(E) The Town disregards flood hazard regs in decision-making

(F) The Town doesn't even know they have flood hazard regs

(G) Other:

Town Floodplain Administrators

1) Do you recall the rationale for how this decision was made? What were the factors you considered when asking these questions?

2) What is the process for permitting in your town—what boards or committees are involved in decision making?

3) Do you ever reject permits or discourage an application on the basis of the proposal's non-compliance with flood hazard regulations?

4) With respect to the decision to permit development in the flood hazard area in your town, which of the following statements feels the most true (please choose only one):

(A) Flood hazard regs are critical to the Town's decision-making

(B) Flood hazard regs are important to decision-making, but the Town takes into consideration other factors.

If B), what other factors?

(C) Flood hazard regs are moderately important to decision-making, but the Town mostly considers other factors

If C), what other factors?

(D) Flood hazard regs are not very important to the town's decision-making

(E) The Town disregards flood hazard regs in decision-making

(F) The Town doesn't even know they have flood hazard regs

(G) Other:

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Image Credit

Figure 1. Meander Belt: Vermont Agency of Natural Resources, https://floodready.vermont.gov/RCFAQ

Figure 2. River Corridor vs. Floodplain: Vermont Agency of Natural Resources, https://eastmontpeliervt.org/community/flood-hazard-information/ (original source unknown).