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PROTECTING RIVER CORRIDORS IN VERMONT[1]

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ABSTRACT: The Vermont Agency of Natural Resources' current strategy for restoring aquatic habitat, water quality, and riparian ecosystem services is the protection of fluvial geomorphic-based river corridors and associated wetland and floodplain attributes and functions. Vermont has assessed over 1,350 miles of stream channels to determine how natural processes have been modified by channel management activities, corridor encroachments, and land use/land cover changes. Nearly three quarters of Vermont field-assessed reaches are incised limiting access to floodplains and thus reducing important ecosystem services such as flood and erosion hazard mitigation, sediment storage, and nutrient uptake. River corridor planning is conducted with geomorphic data to identify opportunities and constraints to mitigating the effects of physical stressors. Corridors are sized based on the meander belt width and assigned a sensitivity rating based on the likelihood of channel adjustment due to stressors. The approach adopted by Vermont is fundamentally based on restoring fluvial processes associated with dynamic equilibrium, and associated habitat features. Managing toward fluvial equilibrium is taking hold across Vermont through adoption of municipal fluvial erosion hazard zoning and purchase of river corridor easements, or local channel and floodplain management rights. These tools signify a shift away from primarily active management approaches of varying success that largely worked against natural river form and process, to a current community-based, primarily passive approach to accommodate floodplain reestablishment through fluvial processes.

(KEY TERMS: river corridor protection; river meander belts; floodplain restoration; erosion hazard zones; river easements.)

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INTRODUCTION

The lands adjacent to river channels are critical to aquatic and terrestrial ecosystems (Allen, 1995; Smith *et al.*, 2008), provide important ecosystem services (Postel and Carpenter, 1997), and are socially important (Millennium Ecosystem Assessment, 2005). The value of river corridors to both aquatic ecosystems and public safety has led the Vermont Agency of Natural Resources (ANR) to invest considerable time and resources to establish a river corridor protection program over the past decade. This approach goes beyond the traditional view of buffers as land use setbacks to maintain water quality. Geomorphic-based river corridors are being established to maintain natural channel form and functions, as well as critical ecosystem services such as flood and erosion hazard mitigation. A science-based approach has allowed the Vermont River Management Program

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(VRMP) to integrate river corridor planning with other public policies and programs, and affect change in river and floodplain management far beyond its limited jurisdiction.

An extensive Internet search reveals that nearly all states promote buffers. States such as Washington, Ohio, and New Hampshire have programs that promote the protection of fluvial geomorphic-based river corridors. Few states have large geomorphic datasets based on rigorous assessment protocols such as now available in Vermont (http://www.anr.state.vt.us/dec/waterq/rivers.htm) to establish river corridors and achieve the programmatic objectives of improving public safety, water quality, and aquatic habitat. This paper will describe aspects of Vermont's river corridor protection program we believe to be unique in the United States at the state level of government. Several facets of developing the River Management Program will be discussed, including a multi-objective planning process designed to leverage outcomes in the development, transportation, agricultural, and recreational sectors of the Vermont economy.

A description of the natural and programmatic setting in which the VRMP was initiated will be followed by an explanation of how the agency shifted its focus from solely restoration to one dedicated to river corridor planning and protection. A brief technical description of Vermont's river corridor delineation process is provided; finally, the paper concludes with several specific examples of how river corridor protection is being promoted under the auspices of local, state, and federal programs in Vermont.

FLUVIAL GEOMORPHOLOGY ADOPTED AS AN ORGANIZING PRINCIPLE

The VRMP was created in 1999 to address the multifaceted environmental and societal threats that derive from unstable streams. Yet prior to this time Vermont experienced decades of disjointed river management where several state programs were working separately toward closely related objectives that were established from federal flood control and environmental programs. A Vermont Stream Alteration Program was established to regulate activities that altered the course, current, or cross-section of larger streams (≥10 sq. miles). Using an engineering approach, the program adopted popular practices of the time and sanctioned the control of stream erosion and the dredging of aggraded sediments to meet its mandate of minimizing flood damage and protecting fish and wildlife. Resolving conflicts between human investments and the dynamics of fluvial systems largely remained an exercise of installing local engineering fixes that amounted to channel armoring.

Meanwhile, the pollution aspects of erosion and sedimentation were being assessed by the USEPA and Vermont's water quality programs. Riparian buffer, wetland, and stream restoration programs were developed. The planners and ecologists plying the restoration trade believed that all erosion was a problem. At this time engineers and scientists were both working to achieve programmatic objectives of improving environmental health and public safety and were designing practices that largely worked against the natural form and processes of river channels.

The National Flood Insurance Program (NFIP) was also established in Vermont to map inundation-related hazards and create an insurance incentive for municipal participation. The science behind Federal Emergency Management Administration (FEMA) floodplain mapping takes a significant step forward, to consider larger spatial scales, but does not consider the degree of channel incision and channel evolution processes underway in Vermont (FEMA, 1999; Kline and Cahoon, 2008). Furthermore, much of the original FEMA inundation-based mapping in Vermont took place after 1970 when the majority of human-altered channels were already incised and disconnected from their floodplains. Mapped FEMA floodways and floodplains in Vermont are therefore more narrow than they may have been prior to alterations in channel geometry and the modification of sediment and hydrologic regimes associated with historic land use changes (Figure 4). This has allowed development to be placed in close proximity to stream channels where risks due to erosion hazards are high.

Five major floods in Vermont during the 1990s resulted in much damage and loss of human life (Vermont Act 137 Report, 1990). The Vermont state legislature requested an accounting of US$60 million in damages at a time when virtually all municipalities were participating in the NFIP, and the authors found that the majority of the losses were associated with erosion and not inundation. The report highlights the high cost and repeated failure of common structural measures used in the attempt to protect near-stream investments and infrastructure by keeping long lengths of river permanently straightened. A need for river management and policy change was evident.

Like many of our counterparts across the country, Vermont's river scientists and engineers sought to shed new light on the erosion issue by linking engineering, water quality, and ecology practices via the discipline of fluvial geomorphology. The study of physical channel form and processes provides a unifying view of a river system from which to study and manage each component of the aquatic ecosystem (Brierley and Fryirs, 2005). Vermont's small size, escalating flood damages, and growing public investment in flood recovery facilitated the merger of the Stream Alteration, Buffer Restoration, and NFIP programs into a single River Management Program. The unifying goal of this interdisciplinary group is to manage toward, protect, and restore natural geomorphic conditions, and avoid new and resolve existing conflicts between human investments and river dynamics in the most economically and ecologically sustainable manner. Promoting (not calculating and imposing) stable channel equilibrium has become an organizing principle for achieving the state's objectives of reducing flood damages; naturalizing hydrologic and sediment regimes; improving water quality by reducing sediment and nutrient loading; and restoring the structure and function of aquatic and riparian habitats.

LESSONS LEARNED FROM ACTIVE RESTORATION

The VRMP began by pursuing large-scale river restoration projects using natural channel design techniques (e.g., Rosgen and Silvey, 1996). These projects were a logical progression from the river engineering work that preceded the formation of the VRMP with a seemingly more naturalized approach. The Trout River Project in northern Vermont (http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_troutreport.pdf) involved extensive channel re-alignment, including many vanes, weirs, and channel blocks to train the river into a designed dimension, pattern, and profile. The project spanned four years, consumed a large percentage of the Program's resources, and required multiple efforts to expand, repair, and modify project components that began failing during the 50, 25, and 5 year floods after construction. The Program began three other large projects around the same time, with more and more of its energy focused backward to shore up restoration sites than was being focused forward.

The learning curve factored into some initial failure, yet fundamentally our approach to naturalized design fell short of, and in some cases worked against, achieving true dynamic equilibrium. Increasingly, project components were weathering floods, but monitoring and assessment showed that projects were not meeting ecological and hazard reduction objectives (Palmer *et al.*, 2005). Quantifying reference channel morphology and large-scale watershed processes, those associated with hydrologic and sediment regime alterations, at the level of precision required for active restoration (Kondolf *et al.*, 2001) was more costly than the state was prepared to support. A host of physical and financial constraints made it very difficult to sustain a statewide watershed restoration program based on natural channel design techniques.

During the construction of active restoration projects in Vermont, it became evident that other river corridors and floodplains in the state were being permanently lost due to the continued placement of permanent investments and infrastructure. New encroachments were emerging faster than active restoration could be designed, permitted, and implemented. The channelization that would be required to prevent their destruction led us to question whether a state program could ever get ahead of this curve. The answer was clear – a protection strategy was needed to create an effective long-term river management approach.

Vermont ANR and its partners have since fashioned a restoration program that embraces the concepts and practices associated with dynamic and deformable rivers (Brierley and Fryirs, 2005). Many of the restoration techniques learned during the early period of the Program remain as valuable assets to be employed where permanent conflicts exist between river processes and infrastructure, but the VRMP now approaches each project with an initial objective of protecting the river corridor from further encroachment. Corridor protection in combination with the active removal of physical constraints (e.g., berms, floodplain fills, and undersized bridges/culverts) are the mainstays of the VRMP restoration program. Geomorphic data and consideration of fluvial process have allowed us to more truly understand river/floodplain deposition and erosion, flood risks, water quality, and habitat condition to form meaningful restoration objectives.

VERMONT RIVERS: THEIR NATURAL SETTING AND PRESENT CONDITION

Vermont developed Stream Geomorphic and Reach Habitat Assessment protocols (VSGA by Kline *et al.*, 2007; VRHA by Schiff *et al.*, 2008), with which the River Management Program and its partners have assessed 8,279 stream miles using remote sensing techniques (VSGA Phase 1) and 1,371 stream miles using rapid geomorphic field techniques (Phase 2) (protocol reviews by Somerville and Pruitt, 2004; Besaw *et al.*, 2009). The data describe Vermont as a headwaters state. Its major rivers fall an average of 700 m from the Green and Taconic Mountain ranges in the Lake Champlain (St. Lawrence River), Connecticut River, and Hudson River watersheds. Approximately two-thirds of the state's 23,000 stream miles are steeper streams (≥2% slope), confined within narrow valleys (≤6 reference channel widths), and exhibit cascade, step-pool, and plane bed morphologies (Montgomery and Buffington, 1997; VRMP, 2009). In addition to bedrock, these streams cut through glacial till and the glacial lacustrine (clayey) material laid down when much of Vermont was covered by lakes impounded by receding glaciers (ca. 13,000 years BP). Braided streams were once common in Vermont at the mouth of narrow valleys where channel gradients abruptly decreased and glacial lake deltas and alluvial fans were found (Bierman *et al.*, 1997). Broader valleys, comprised of alluvium and glacial lacustrine floodplains and terraces, punctuated by bedrock outcrops controlling channel slope, host the remaining Vermont stream miles and promote riffle-pool and ripple-dune morphologies with the latter being more common in the lowlands surrounding Lake Champlain and Lake Memphremagog.

Ongoing postglacial, isostatic rebound of Vermont landforms, climatic shifts between wet and dry periods, and the response to widespread land use/cover change over the past two centuries are the dominant drivers of the fluvial erosion and deposition (Brackenridge *et al.*, 1988; Bierman *et al.*, 1997). Stream channels are eroding into rebounding strata and have formed, abandoned, and reformed floodplains at lower elevations over time (Schumm, 1977). In Vermont, the degree and rate of this natural channel evolution has been altered. After six years of conducting geomorphic assessments throughout Vermont, 73.7% of the 1,371 miles of Phase 2 field assessed streams (i.e., involving measured cross-sections, Kline *et al.*, 2007) have lost physical connection with their historic floodplains (Table 1) (VRMP, 2009). Channel incision is pervasive, especially in the lower gradient stream types. An analysis of Vermont data shows that most streams and rivers, not controlled by bedrock, are incised and lack access to floodplains during frequent floods (1- to 10-year recurrence) and in some cases less common floods (50- to 100-year recurrence). The containment of flood flows has resulted in a tremendous increase in stream power and channel adjustment and erosion. Simon and Rinaldi (2006) remind us that accelerated channel incision is the "quintessential feature of dis-equilibriated fluvial systems," and it is this condition that assessment data show to be widespread in Vermont.

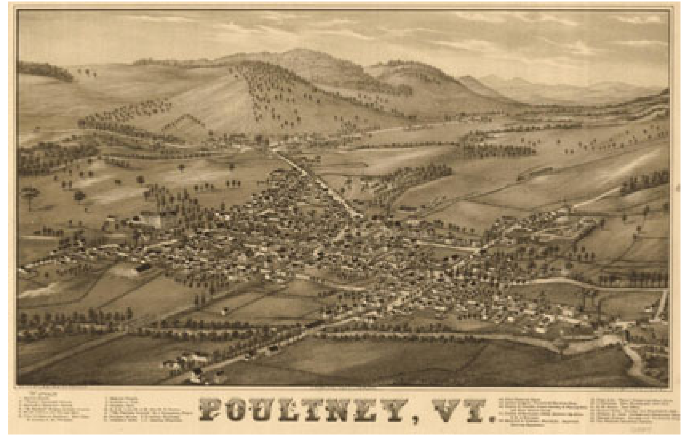

FIGURE 1. Straightened Vermont River (ca. 1860) in a Deforested, Rural Village Setting. Used by permission from the Vermont Historical Society.

Geomorphic assessments also show that streams and rivers have been greatly altered during the past two centuries in Vermont by human-imposed changes to the width, depth, slope, and sinuosity of rivers in association with watershed and riparian land uses (VRMP, 2009). Historic and present-day stressors, include: deforestation (80% of the state ca. 1900, Figure 1) (McGrory Klyza and Trombulak, 1999); clearing of headwater streams for log drives; ditching wetlands; straightening, berming, and armoring channels to accommodate roads and other encroachments (Figure 1); damming and diversions; commercial gravel extraction for the state's road system; and paving and ditching in urbanizing parts of the state. Accumulated valley sediments originally placed by melting glaciers and later mobilized by widespread deforestation are now being worked by streams and rivers that are more powerful due to reduced floodplain

TABLE 1. Vermont Phase 2 Stream Geomorphic Assessment (2002-2008) of Channel Evolution Stage. Stages II-IV (Schumm, 1984) represent departures from equilibrium where floodplain access and attenuation functions are reduced.

Evolution Stage	Adjustment Processes	Miles	Percent
I	In dynamic equilibrium, only minor vertical and lateral adjustment	342	25
II	Major channel degradation, annual floods not accessing a floodplain	305	22
III	Channel widening, as increased flood energy erodes streambanks	503	37
IV	Major channel aggradation, juvenile floodplains begin forming	203	15
V	New floodplains formed and dynamic equilibrium restored	18	1

access, channel straightening, and reduction in hydraulic roughness (VRMP, 2009).

Many straightened, incised reaches are now widening and aggrading. Storm events energize these river systems with inputs of water and sediment, and accelerate widening and aggradation processes, as new floodplains develop along the rivers. The vertical and lateral adjustment processes, most commonly observed as streambank erosion and bar building, result in planform or meander changes that occur as the channel slope and energy gradient adjust in equilibrium with watershed inputs (Leopold, 1994). Vermont's assessments are revealing that the channelization, made necessary to protect land use investments, has also led to a loss of sediment storage and a net export of life-giving soil and nutrients from a watershed.

Under natural conditions, periodic flood-related disturbances create and maintain the tremendous habitat diversity within aquatic and riparian ecosystems (Poff *et al.*, 1997; Baron *et al.*, 2003). Disruption of flood cycles and the widespread physical manipulation of rivers is a major factor in the decline of aquatic ecosystems worldwide (Abramovitz, 1996). The VRMP has been working to find acceptable alternatives to channelizing streams for flood and erosion control, and to protect existing functional riparian corridors.

FLUVIAL GEOMORPHIC-BASED RIVER CORRIDOR PLANNING

Stream classifications and descriptions of erosion-deposition process and equilibrium concepts offered by Schumm (1984), Simon and Hupp (1986), Rosgen and Silvey (1996), Montgomery and Buffington (1997), and Brierley and Fryirs (2005) have all been extremely useful and accessible for communicating stream types, behavior, and stressor-response conditions in Vermont assessments and the development of river corridor plans. Vermont uses its fluvial geomorphic data to provide critically important information on: (1) *stream condition*, or the degree of departure of existing geomorphic form and process from a reference condition, either observed or extrapolated from valley and watershed characteristics; (2) *sensitivity*, or the likelihood that a stream, based on its morphology, sediment regime type, geology, boundary resistance, and stream condition, will respond to a watershed or local disturbance caused by a natural event and/or anticipated human activity; and (3) *adjustment process*, or type of vertical or lateral channel movement, that may be underway due to natural causes or human activity that has or may result in a change to the stream condition. These characterizations are central to problem solving and planning in a "systems" or watershed context (Kline, 2009).

VRMP corridor plans describe stream condition and the type and degree of channel adjustments that occur in response to (1) changes in hydrology and sediment load, (2) the magnitude and frequency of flood events, and (3) the channel and floodplain modifications that have been conducted in a watershed. The departure and sensitivity of reaches are mapped in the context of vertical and lateral channel constraints throughout the stream network to explain the channel evolution processes underway (VRMP, 2009). River corridor plans identify reach-specific protection and management practices that may preserve existing fluvial processes and accommodate the restoration of equilibrium conditions over larger spatial and temporal scales.

The VRMP used FEMA Predisaster Mitigation Program funding to initially support assessments and corridor planning. State and federal water quality and habitat remediation funds also began supporting assessments and corridor planning as the close link between channel disequilibrium and instream flow alteration, excessive sediment and nutrient loading, and habitat impairment became evident (Vermont Water Quality Division, 2006). The coalition of watershed associations, regional planning agencies, and conservations districts, heavily involved in the bioengineering era of restoration work, became vital partners with the VRMP to sponsor assessments, planning, and restoration projects. The VRMP multi-objective approach (hazards, water quality, and habitat) has translated into local constituencies that bring landowners and municipal officials to the corridor planning table.

DEFINING RIVER CORRIDORS

For decades, river ecologists, including the authors, have advocated for the establishment of riparian buffers as a development setback. It is the contention here that, in combination with the delineated floodplain, the river corridor, a dynamic valley-bottom area that accommodates the dimension, pattern, and profile of a stream channel in its most stable equilibrium condition, is the appropriate spatial context to reduce long-term river-human conflict. We delineate river corridors based on existing and estimated meander belt width.

Where rivers are assessed as being at or near equilibrium, the lateral most extent of meanders is used

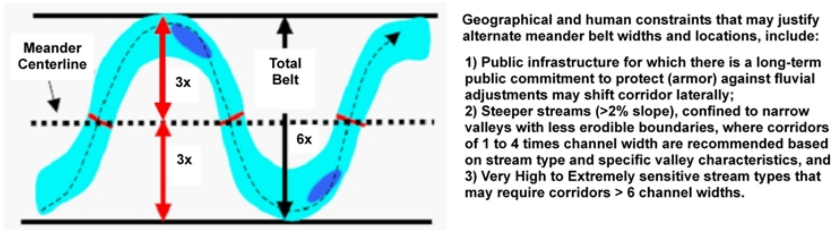

FIGURE 2. Schematic for Drawing the Outer Belt Width Lines of a Low Gradient, Meandering Channel. Lines capture the extent of existing meanders or located in equal measure from a meander centerline drawn through meander inflection points, located at each meander cross-over. Exceptions to the six times channel width are indicated (Kline, 2008a).

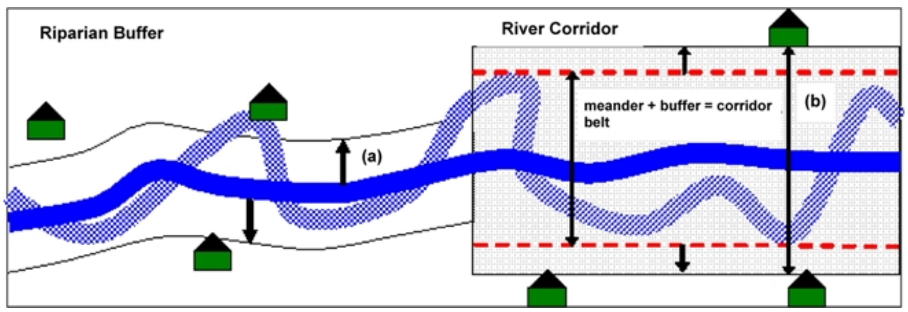

FIGURE 3. Comparing a Top-of-Bank Buffer Setback (a) to a River Corridor (b). Corridor includes a buffer allowance added to the meander belt. This example shows a typical straightened river shadowed by a meander geometry to which it may evolve. The degree of conflict with future encroachments is illustrated (houses placed in conformance with setback requirement). Source: Adapted by permission from Ohio Department of Natural Resources (DNR) (2006).

to inform the width calculation and delineation of a meander belt. Many Vermont channels, however, have been straightened and/or moved against the toe of the valley to create space for transportation corridors and agriculture (VRMP, 2009). In these cases, the meander belt width (B) is estimated as a function of channel width (W); $B = 4.3W^{1.12}$ (Williams, 1986). The belt width is thus equal to approximately six bankfull channel widths. River corridors for low-gradient streams (slope $\leq 2\%$) in narrow to broad alluvial valleys are calculated to accommodate a meander belt width that is equal to six times the width of the reference channel (Figure 2), plus an additional reference channel width added to either side of the meander belt to provide space for minimal vegetated buffer functions (Figure 3). In this case, the total river corridor width would be equal to eight reference channel widths, drawn using four reference channel widths on either side of the meander centerline or extended laterally eight reference channel widths out from the valley toe (Kline, 2008a). River corridor width may need to be expanded or reduced due to permanent infrastructure (e.g., state highways) that must be protected, confining valley characteristics, or from the identification of highly dynamic, sensitive stream channel locations. Vermont has developed regional hydraulic geometry curves to aid in the estimation of reference channel widths (Jaquith and Kline, 2007), and a GIS Stream Geomorphic Assessment Tool (VRMP, 2009) to automate the process of delineating river corridors once the streams, valley walls, and meander centerlines are defined.

River corridors are established as the most likely area where channel adjustments may occur, equilibrium condition may become re-established, and the minimization of work (i.e., erosion) takes place (Leopold, 1994). It is possible that channels will migrate outside of a delineated river corridor due to extreme events such as channel avulsions due to large floods or landslides. VRMP is careful to explain in public forums that river corridors are a management tool for accommodating equilibrium conditions and achieve the ecosystem services thereof, and not intended to capture all possible river locations.

In the authors' experience, top-of-bank buffer setbacks are regularly promoted with the misperception that rivers are static in the landscape. Landowners and resource agencies in Vermont have armored streams in disequilibrium to stop the erosion of an established buffer, and thus static buffers become another investment that are every bit as immutable in people's minds as other forms of development next

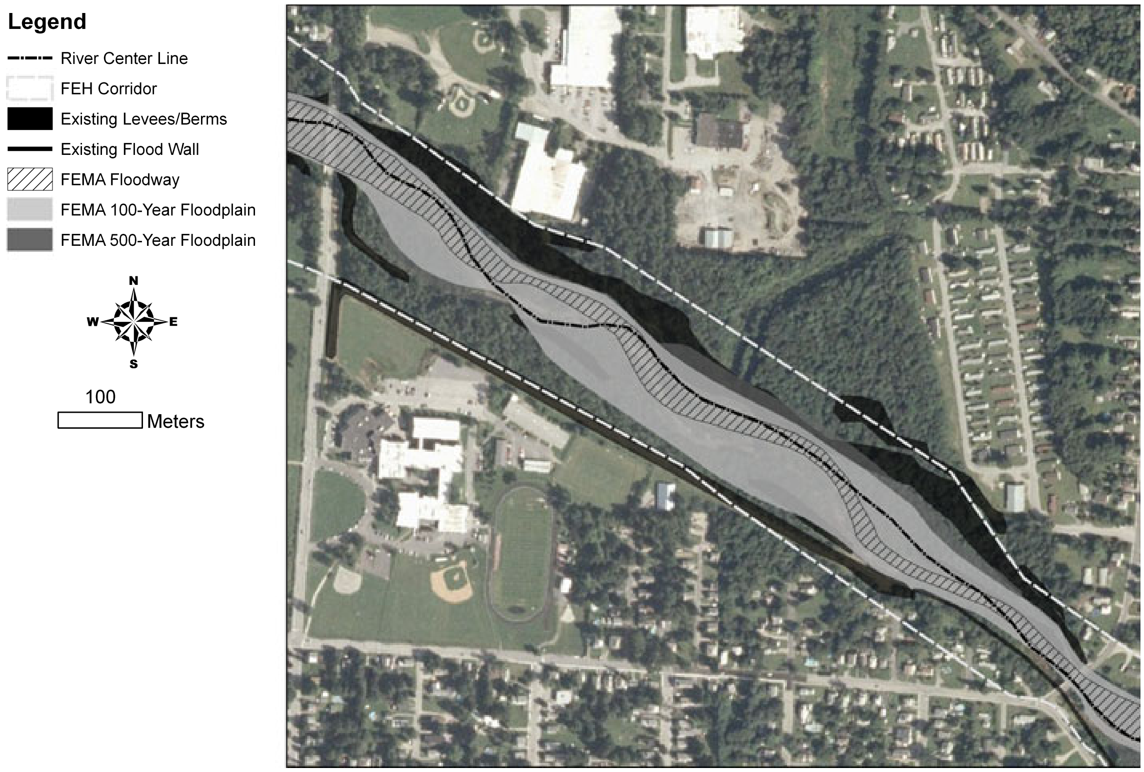

FIGURE 4. Municipally Adopted FEH Zone Providing Greater Setback Protection Than NFIP Floodway and Floodplains on Roaring Branch in Bennington, Vermont. VRMP data show contracted 100 year floodplain a result of deep incision from historic dredge and berm activities. Note existing river centerline in relation to 1986 floodway.

to rivers. Establishing a narrower buffer while leaving the river corridor unprotected invites future encroachments in high risk locations and misses the opportunity to provide enough space for stream processes and equilibrium to occur (Figure 3). Once people build within the corridor, it is compromised, and a costly ongoing channelization program to protect those investments is often politically and socially required.

RIVER CORRIDOR PROTECTION IN VERMONT

Two primary mechanisms for river corridor protection have been developed by the VRMP, including: (1) state and municipal land use restrictions on development within defined fluvial erosion hazard (FEH) areas and (2) a program to support the purchase of development and channel management rights in river corridor conservation easements. These practices are the main components of Vermont ANR's river corridor protection strategy for managing rivers toward equilibrium conditions, often used in conjunction with active river restoration practices.

Fluvial Erosion Hazard Areas

Vermont ANR has established an FEH risk assessment and mapping methodology (Dolan *et al.*, 2008) based on the delineation of fluvial geomorphic-based river corridors as described above. The Vermont ANR uses both FEH and FEMA NFIP hazard areas in regulating developments proposed within floodways and the floodway fringe falling under the jurisdiction of the Vermont land use development law (Act 250). In addition, FEH maps are provided to Vermont municipalities as part of the FEMA-sponsored state and local predisaster mitigation planning. In many cases FEH zones increase the required setback beyond the effective FEMA floodway and floodplain (Figure 4). This is due to channel incision, the lack of floodplain connection, and the likelihood of subsequent channel slope and planform adjustment. The River Management Program assists Vermont communities in establishing FEH areas as part of municipal flood hazard zoning districts. Project reviews and map revisions are conducted in a manner similar to that provided through FEMA's Community Assistance Program. Five Vermont towns have adopted FEH zones, and over one-third of Vermont's 251 municipalities are at different stages in the geomorphic assessment, FEH zone development, and bylaw adoption process. The FEH zoning overlay comes with the incentive of state assistance to reduce flood and erosion hazards and increase public safety. For example the Roaring Branch Floodplain Restoration Project depicted in Figure 4 is part of a state-municipal partnership. The state is seeking to remove existing nonengineered, human-constructed berms to restore floodplain, and the town is looking for assistance to remove excessive sediment accumulation at several bridge locations. The town has adopted an FEH bylaw to stop future encroachment.

River Corridor Easements

A dozen river reaches have been protected under the new Vermont river corridor protection easements where channel management rights are purchased, permanently protecting the river from armoring and channelization (Kline, 2008b). Opportunities for corridor protection are initially identified in river corridor plans based on fluvial geomorphic field data. The opportunity to purchase and sell river corridor easements was created to augment the municipal FEH zoning ordinance. Zoning may avoid future encroachment and minimize FEH, but does not restrict channelization practices. The societally ingrained notion to stop all erosion, even where few investments are at risk, limits the channel evolution process and prolongs the attainment of equilibrium conditions.

The purpose of the river corridor easement is to give the river the space to re-establish a natural slope, meander pattern, and floodplain connection. The VRMP river corridor easement creates the opportunity within the river corridor to establish a naturally vegetated floating buffer measured from the river banks as they move (Kline, 2008b). The easement holder, typically local and statewide land trusts, work with local watershed organizations to establish and maintain buffers. A floating buffer is in contrast with the static buffers described in the previous section. The landowner may continue to conduct agriculture and forestry within the river corridor outside the naturally vegetated buffer to preserve traditional land uses. The landowner is restricted within the corridor and has sold the rights to place, repair, or modify structural elements such as revetments, levees, or earthen fills. The landowner may not manipulate the natural watercourses, wetlands, or other water bodies in a manner that will alter the natural water level or flow, or intervene in the natural physical adjustment of water bodies and floodplain formation within the easement corridor. In other words, the river is free to naturally migrate.

The River Management Program has established a corridor appraisal calculator, based on soils, land use, and river sensitivity to adjustment that determines a monetary value to be given to the landowner as compensation for the river corridor easement. The Program works closely with state and federal farm service agencies to combine corridor easements with enrollment in agricultural programs, such as the state-enhanced, USDA Conservation Reserve Program, used to contractually take buffer lands out of agricultural production. The one-time payments are a large cost-savings to the taxpayer when compared with the public dollars used to support the never-ending battle to keep certain river reaches channelized and static in the landscape for infrastructure protection.

The State of Vermont utilizes river corridor easements and the river corridor planning process to protect "key attenuation assets" to counterbalance pervasive increases in water and sediment transport. Attenuation areas are vegetated riparian floodplains and wetlands that store flood flows and sediments and reduce the transport of organic material and nutrients from the watershed. Focusing the limited conservation dollar on easements to protect attenuation assets, and the ecological processes they provide, is a critical component of Vermont corridor planning and protection.

Restoration and Mitigation in Tandem With Corridor Protection

FEH zoning and river corridor easements require towns and landowners to change land use expectations beyond traditional static buffers and the ability to site infrastructure in risky locations. The VRMP works with its sister agencies and partners to offer funding and technical assistance in support of local projects that are part of a larger river corridor protection initiative. For instance, floodplain restoration projects, riverbed and bank stabilization within village centers, bridge and culvert work at common road washout areas and fish blocks, and property relocation have all been offered and implemented as incentives to achieve the larger objective of corridor protection. A key aspect of this strategy is the collaboration and consistency with state, federal, municipal, and nonprofit programs. The VRMP is diligent in working with its public and private partners to integrate geomorphic data and corridor planning outputs into agricultural, forestry, transportation, land use, stormwater, and fish and wildlife planning through funding and technical assistance programs. Under the new Vermont river protection and restoration approach, landowners and towns seeking to resolve their river conflicts will increasingly get consistent guidance and support for corridor protection and working toward natural equilibrium.

CONCLUSION

River management in the state of Vermont has evolved to combine limited state meander belt regulation with a greater emphasis on landowner and municipal incentives to protect river corridors in pursuit of a risk avoidance strategy. Agency managers combined once disparate river-related programs; adopted a unifying goal to address multiple objectives; and combined state, federal, and local constituency resources to conduct fluvial geomorphic assessments. Data support river corridor planning to identify projects and practices that will contribute to the long-term, sustainable management of unstable streams. The protection of river corridors, especially key attenuation assets, has emerged as the highest priority. Isolated restoration projects, completed in the absence of corridor protection, have proved to be unsuccessful over time. Given the impending high rate of land use conversion and river encroachment, if Vermont fails to protect its river corridors, a relatively rural state would have lost a real opportunity for true watershed-scale restoration and protection. We surmise that other rural, mountainous states, with similar river and land use histories, may be on a similar precipice with respect to river management policy. As our population and economy grow and our climate changes, the conflict between what is a physical imperative of the river system and our land use expectations will become more intractable.

The VRMP is working with its partners to focus on the long-term benefits of a fluvial geomorphic management approach for both property owners and riparian ecosystems. The largest challenge will not be in applying the science to understand the river's slope and planform requirements, but rather how to redefine the relationship of public and private investments with fluvial dynamics in an equitable manner over time within a valley. The short-term costs associated with using a geomorphic-based approach, where land conversion is necessary, become more acceptable and economically justifiable where channelization projects have failed repeatedly, or in post-flood remediation, where major erosion, property damage, and channel avulsions have occurred. The VRMP acknowledges the importance of a passive restoration approach, wherein the river, largely freed of human physical constraints, may use its own energy and watershed inputs to re-establish the fluvial processes associated with equilibrium conditions over the long term. A passive approach may often be the most desirable alternative due to its lower upfront costs and maintenance, but like active restoration, it is highly dependent upon reducing watershed stressors, and landowner willingness to accept changes in land use. It is extremely important that state and federal agencies involved with river resource management work together to provide a consistent message, economic incentives, and technical assistance to towns and landowners to help promote decisions that resolve immediate conflicts with the long-term watershed solutions in mind.

The social, economic, and ecological return for implementing river corridor management practices that work toward equilibrium at the watershed scale will be enjoyed by generations to come. The long-term challenge is minimizing risk to investments, reducing erosion, supporting healthier aquatic ecosystems, and reducing short-term economic losses along the way. Agencies should revise and strengthen their policies and programs to promote a sustainable relationship with river ecosystems, and reach out to organizations and municipalities doing important and significant work on farms, forests, roads, and other community assets. Promoting river corridor protection should reach the public and landowners primarily through education, example, incentive, and local land use planning. Vermont RMP is working to model its own "riparian ethic" (Naimen *et al.*, 2005), and shares this story of an evolving rivers program to help promote river corridor protection.

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