GIVING OUR RIVERS ROOM TO MOVE: A NEW STRATEGY AND CONTRIBUTION TO PROTECTING VERMONT'S COMMUNITIES AND ENSURING CLEAN WATER

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I. STREAMBANK AND CHANNEL EROSION—DEFINING THE PROBLEM

A. The Loss of Watershed Storage

Lake Champlain and the Green Mountains share an intertwined geologic history that continues today and is highly relevant to discussions about how to protect the quality of Lake Champlain. The Green Mountains have been scraped, carved, and eroded by wind, water, and glacier.[2] Large glacial lakes have come and gone, lands have rebounded from the massive weight of the glaciers, and rivers have cut down, reforming the steep and narrow valleys they once occupied.[3] These fluvial geomorphic[4] processes continue today.[5] The Vermont bedrock, surficial geology, and soil maps explain the complex origins of alluvial (i.e., river-borne) materials that deliver phosphorus as they are eroded down-valley to Lake Champlain.[6] Efforts to restore the lake by reducing sediment and nutrient pollution loads must take these processes into account.

Because natural rivers are dynamic flowages of water, sediment, and wood debris, they are constantly eroding and depositing.[7] Watershed total

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2. MIKE WINSLOW, LAKE CHAMPLAIN COMM., GLACIERS & THE CHAMPLAIN WATERSHED 15 (2016), http://www.lcmm.org/navigating/QuadCurriculum_Glaciers.pdf [https://perma.cc/R9TD-D3Y7].

3. Mike Winslow, *A Natural and Human History of Lake Champlain*, *supra* pp. 489–91.

4. Fluvial geomorphology is the science explaining how the forces and processes of flowing water, sediment, and woody debris create the different surface features and landforms of a watershed—from the small stream to the large river setting over long periods of time. Rivers are understood in their natural setting and how they respond to human-induced changes in a watershed. VT. AGENCY OF NAT. RES., STREAM GEOMORPHIC ASSESSMENT 2 (2016), http://dec.vermont.gov/watershed/rivers/river-corridor-and-floodplain-protection/geomorphic-assessment [https://perma.cc/XJM2-QYA7].

5. Mike Kline & Barry Cahoon, *Protecting River Corridors in Vermont*, 46 J. AM. WATER RESOURCES ASS'N 230 (2010).

6. MIKE KLINE, VERMONT AGENCY OF NAT. RESOURCES: RIVER CORRIDOR PLANNING GUIDE 2 (2010), http://dec.vermont.gov/sites/dec/files/wsm/rivers/docs/rv_rivercorridorguide.pdf [https://perma.cc/PR58-D7MF].

7. MARK P. SMITH ET AL., THE ACTIVE RIVER AREA: A CONSERVATION FRAMEWORK FOR PROTECTING RIVERS AND STREAMS 1 (2008),

maximum daily load ("TMDL") models addressing the ill-effects of human-caused eutrophication will factor a natural background level of watershed erosion that will always be delivering nutrients to the receiving waterbody during precipitation events.[8] None of Vermont's larger basins are in a condition, however, to obtain an empirical signal of the watershed "base-load" of eroded sediments at the mouths of the rivers because human hands have increased erosion in unstable rivers from the smallest headwater streams to the largest river reaches in Vermont.[9]

What is measured instead is the loss of natural watershed storage, or the loss of those landscape features where water, sediment, and woody material would be captured and held during storm events. Storage occurs when the depth and velocity of floodwater is reduced and its suspended sediments are precipitated and held to the land surface by physical, chemical, or biological means.[10] Beaver ponds, wetlands, floodplains, and naturally-vegetated riparian lands are natural features and their existence and contribution to watershed storage has been significantly depleted in Vermont over the past 200 year.[11] It should be noted, however, that these features do not permanently store the nutrient they capture, i.e., natural base-level erosion would still occur, but at a lower rate than that which is measured today. As will be discussed below in more detail, we have learned that by investing in the protection of these natural features, we restore river systems closer to a state of equilibrium, which results in significant water quality benefits.

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http://www.floods.org/PDF/ASFPM_TNC_Active_River_%20Area.pdf [https://perma.cc/S7BW-DQ7S].

8. KATHRYN MORSE & DIANE MUNROE, PHOSPHORUS LOADING IN LAKE CHAMPLAIN i (2011), http://www.middlebury.edu/media/view/276855/original/final_compiled_small.pdf [https://perma.cc/Y5KJ-Y4U7].

9. *Vermont Stream Geomorphic Assessment Data and River Corridor Plans: Vermont Rivers Program Data Management System (DMS)*, VT. AGENCY OF NAT. RES., https://anrweb.vt.gov/DEC/SGA/Default.aspx [https://perma.cc/N4B4-NSCE].

10. *What Is a Watershed?*, U.S. GEOLOGICAL SURVEY, http://water.usgs.gov/edu/watershed.html [https://perma.cc/2CNQ-5ME6] (last visited Apr. 16, 2016).

11. *Vermont Stream Geomorphic Assessment Data and River Corridor Plans*, *supra* note 9.

B. Human-Related Drivers Increasing Sediment Transport

Streambank and channel erosion are increased when the power of the flowing water exceeds the resistance of the channel bed or bank materials to being moved.[12] Stream power is essentially a function of the depth and slope of the flowing water (Figure 1). Erosion is negligible during dry periods when water levels are shallow and lower in gradient due to the meandering pattern of the stream.[13] Movement of bed and bank materials will increase during a flood (e.g., spring runoff) when water depths are greater and flows have a higher gradient due to the straighter, down-valley path of the flood.[14]

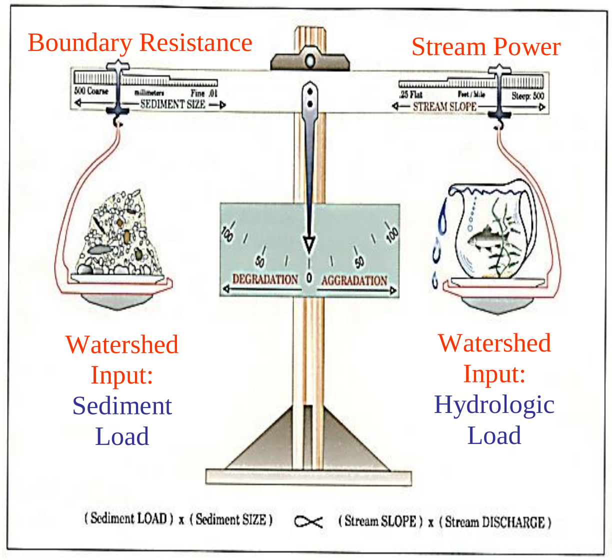

Figure 1: Balance explaining the factors of stream equilibrium (Lane, 1955). Graphic reprinted by permission from Wildland Hydrology, Inc.

Rivers erode and move in the landscape, but have the ability over time to transport the flow, sediment, and debris of their watersheds in such a manner that they generally maintain their dimension (width and depth), pattern (meander length), and profile (slope) without aggrading (building up) or degrading (scouring down).[15] A stream that is moving laterally on the valley floor, while maintaining its basic geometry and vertical position, is

12. KLINE, *supra* note 6, at 2–3.

13. *See* Brian Wu, *Great Lakes' Water Levels Cause Erosion Concern*, SCI. TIMES (Dec. 31, 2014, 3:29 PM), http://www.sciencetimes.com/articles/2259/20141231/lake-huron-water-levels-cause-erosion-concern.htm [https://perma.cc/7FLE-EJTA] (highlighting scientists' concern that high water levels lead to erosion).

14. Christine Kemker, *Sediment Transport and Deposition*, FONDRIEST ENVTL., INC., FUNDAMENTALS OF ENVT. MEASUREMENTS (Dec. 2014), http://www.fondriest.com/environmental-measurements/parameters/hydrology/sediment-transport-deposition/ [https://perma.cc/X4RS-GCUN].

15. *See* SMITH, *supra* note 7, at 6 (explaining a river's ability to maintain equilibrium through constant reformation).

said to be in dynamic equilibrium.[16] Many rivers and streams in Vermont are not in an equilibrium condition due to human-imposed changes in (a) the condition of their bed and banks; (b) the channel slope and meander pattern; and/or (c) the quantity of flow and sediment inputs.[17] Vermont watersheds are in vertical adjustment (i.e., they are either eroding downward through sediment, or building up as a result of sediments deposited from upstream erosion) from the following sequence of events:

- Deforestation—the widespread clearing of forests that occurred in nearly every part of Vermont over the past 200 years "led to dramatic increases in the volume of water and sediment runoff." [18] Channels and floodplains were often buried in over three feet of sediment, "much of it glacial lake sediments that had yet eroded from higher on the valley perimeter. The channels rose up, then eroded back down through these materials, but terraces [i.e., high floodplain features] inaccessible to the rivers remain as a legacy of historic statewide deforestation;"[19]
- Snagging and ditching – "clearing boulders, beavers, and woody debris for logging (sluicing logs from uplands to village mill sites) and flood control, and ditching poorly-drained land for agricultural improvements increased the rate of water and sediment runoff. Many pristine-looking mountain streams in Vermont contain only a fraction of their former channel roughness and resistance, and store far less sediment and debris" than they did before European settlement;[20]
- "Villages, farms, roads, and railroads – early settlements led to the first attempts to channelize rivers and streams, resulting in increased channel slope, stream bed degradation (incision), and floodplain encroachments. Drainage Societies were started over 100 years ago to straighten and channelize streams to accommodate farms and early settlements. These channel works have been periodically maintained through gravel removal, realignment, channel armoring, and extensive flood

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16. GEORGE ZAIMES & ROBERT EMANUEL, STREAM PROCESSES PART I: BASICS 6 (2006), http://www.extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1378g.pdf [https://perma.cc/GB8X-3PFD].

17. MIKE KLINE, ALTERNATIVES FOR RIVER CORRIDOR MANAGEMENT (2006), http://dec.vermont.gov/sites/dec/files/wsm/rivers/docs/rv_managementAlternatives.pdf [https://perma.cc/5FJR-ZTAU].

18. *Id.* at 2.

19. *Id.*

20. *Id.*

remediation projects" and have left a legacy of unstable river systems with increased erosion;[21]

- "Mills, dams, and diversions – led to alterations in the amount and rate of water and sediment runoff. While dozens of dams are in place in each Vermont watershed today, historically there were hundreds. The small mill ponds of yesteryear have been replaced by larger dams used for hydroelectric generation and the creation of impoundments for flood control."[22] Any effort to restore river systems to equilibrium and to address water quality must take these alterations into account;
- "Gravel removal – advocated as a way to maintain straighter, deeper channels and control flooding; large-scale gravel mining resulted in bed degradation, head cutting, channel over-widening, and severe bank erosion. The interstate highways, state roads, and thousands of miles of dirt roads in Vermont were built on materials commercially extracted from the State's rivers;"[23]
- Encroachments, stormwater, and urbanization—have "resulted in increased impervious surfaces and ditching to support economic development. Land use conversions have increased the rate and volume of water relative to sediment runoff, thereby contributing to channel incision and enlargement." Development and use of "lands previously occupied by river meanders or inundated during floods has created unrealistic and unsustainable human expectations in the absence of continuous or periodic channel management activities."[24]

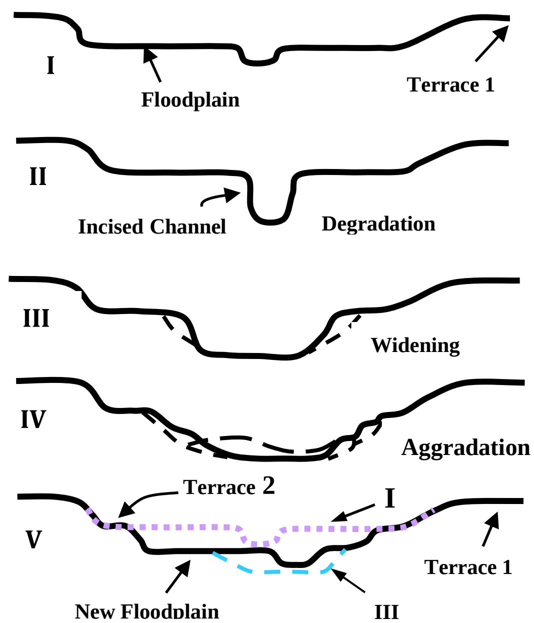

Figure 2: Five stages of channel evolution after Schumm (1984) and Simon and Hupp (1986).

The combination of these watershed,

21. *Id.*
22. *Id.*
23. *Id.*
24. *Id.* at 2–3.

floodplain, and channel modifications led to increases in stream power and more highly erodible channel boundaries, which is why today Vermont streams are moderately to severely incised.[25] Straightened, steepened channels are now adjusting or "evolving" back into more sinuous, gentle gradient channels through a widening and aggradation process (Figure 2).[26] If we are successful in giving our rivers room to recover equilibrium through a mix of the public policy approaches described below and captured in the Lake Champlain TMDL implementation plan, we will see a significant improvement in water quality, first in the streams and rivers themselves, then ultimately in Lake Champlain.

C. Fluvial Geomorphic Assessment Explains Erosion

Stream geomorphic assessments are conducted in Vermont to confirm a stream's departure from equilibrium, its historic and ongoing channel adjustments, and its sensitivity to change. The departure analysis examines those human-caused stressors that create disequilibrium. Meander belts (i.e., those lands defined by the lateral extent of meanders) are the basis for river corridors, which are delineated to examine whether stressors have changed the channel planform and slope expected within different valley settings.[27] Vermont documented the modifications that changed channel slope, depth, and bed and bank conditions and therefore the equilibrium equation (Figure 1). Geomorphologists constructed watershed maps to compare changes in the sediment transport between reference (i.e., background) and existing conditions. From these data and maps, the Vermont river scientist understands the origin of river instability, the stage of channel evolution within the stream network, and the channel and floodplain management practices that would be required in managing streams through the evolution process toward an equilibrium condition. In summary, streambank and channel erosion is contributing to the impairment of Lake Champlain water quality because (a) human-generated stormwater is increasing flood peaks, making streams more powerful; (b) channelization practices (e.g., dredging, berming, straightening, and armoring) have increased channel depth and slope, making streams more powerful; (c) removal of riparian vegetation and instream woody debris have reduced channel resistance, making streams more powerful; and (d) powerful, transport-dominated streams have deepened significantly and

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25. *Id.* at 3.
26. *Id.*
27. Kline & Cahoon, *supra* note 5, at 5.

have far less access to floodplains and riparian wetlands where sediment and nutrient storage may occur.

Unstable streams and the loss of natural watershed storage is the legacy of deforestation, land drainage, and floodplain encroachment.[28] This body of work was used to develop the Environmental Protection Agency's ("EPA") Lake Champlain TMDL and the strategies within Vermont's Implementation Plan.

Understanding this problem provides an important roadmap to developing long-term, effective solutions that will benefit Vermont communities through reduced flood damage, improved fish and wildlife habitat, and better water quality.

II. SOLUTIONS

A. Institutional Changes—Creating a Rivers Program

1. Unique State Program with New and Evolving Span of Control

During the time period for which TMDLs have been in place for Lake Champlain, Vermont has created a Rivers Program and increased its span of control.[29] It is rare, if not unique, in the U.S. for a state to have a program charged with the regulation of activities affecting the physical integrity of both rivers and floodplains to achieve water quality, ecological integrity, and public safety goals.

Many state environmental programs began in response to federal law and funding. Like other states, Vermont started separate river-related programs to address specific issues identified by Congress in the Fish and Wildlife Coordination Act of 1934,[30] the National Flood Insurance Act of 1968,[31] and the Water Pollution Control Act of 1972.[32] Vermont was not alone in failing to appreciate the connection or synergy between the practices needed to address seemingly disparate social, environmental, and economic problems. By the 1990s, Vermont could count more than a dozen

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28. *Id.*
29. *Rivers Program*, VT. DEP'T OF ENVTL. CONSERVATION, http://dec.vermont.gov/watershed/rivers [https://perma.cc/E22C-DV94] (last visited May 3, 2016).
30. Fish and Wildlife Coordination Act of 1934, 16 U.S.C. §§ 661–667(e) (1934).
31. National Flood Insurance Act of 1968, 42 U.S.C. §§ 4001–4131 (2014).
32. Federal Water Pollution Control Act of 1972, 33 U.S.C. §§ 1251–1388 (2008).

programs spread over numerous state agencies affecting the quality and quantity of stream and floodplain resources.[33]

While Vermont still works to address program segregation, the innovations forwarded in the Department of Environmental Conservation ("DEC") TMDL Implementation Plan for increasing stream equilibrium and natural floodplain function can be largely attributed to the building of its current-day Rivers Program.[34] The integration began in 1965 when the Vermont General Assembly promulgated a statute for the regulation of stream flow,[35] which applied to the construction and operation of dams and diversion and called for state governance of activities that would change, alter, or modify the course, current, or cross section of any watercourse. The passage of this statute was unique at the time in establishing standards to achieve social, environmental, and economic-based outcomes (e.g., public safety, property protection, and fish and wildlife protection).

In the early years, the state stream alteration engineer was focused primarily on projects to ensure public safety and infrastructure investments.[36] However, the extensive gravel mining and channelization of rivers, which were sought as a source of materials for state and federal highway construction and perceived as a method for flood control, was met with vocal protest from Vermont anglers and led to the passage of the 1988 Rivers Bill, limiting river gravel extraction.[37] The bill also linked stream alterations to the detriment of Outstanding Resource Waters ("ORW").[38] It created the ORW designation specific to the non-degradation provisions of federal and state anti-degradation policy to limit new hydropower dams and diversions.[39] Through the early 1990s, DEC strengthened its capacity to limit water quality degradation from in-stream structures and activities, including shifting its river management engineers from the Facilities and Engineering Division to the Water Quality Division.

The 1990s were a time when EPA was accelerating its shift from point to nonpoint source pollution control. Many states, including Vermont,

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33. *Department and Program Descriptions*, VT. AGENCY OF NAT. RES., http://anr.vermont.gov/about_us/central-office/departments-programs [https://perma.cc/V8EB-NWHU] (last visited Apr. 2, 2016).

34. VT. AGENCY OF NAT. RES. ET AL., VERMONT LAKE CHAMPLAIN PHOSPHORUS TMDL PHASE 1 IMPLEMENTATION PLAN 50–51 (2014), http://dec.vermont.gov/sites/dec/files/wsm/erp/TMDLcmnts/LCTMDLphase1plan.pdf [https://perma.cc/GWT5-SX5P].

35. VT. STAT. ANN. tit. 10, § 1001 (2016).

36. Kline & Cahoon, *supra* note 5, at 228.

37. *Id.* at 230.

38. No. 138. An Act Relating to Regulation of Flood Hazard Areas, River Corridors, and Stream Alteration, VT. STAT. ANN. tit. 10, §1021. (linking stream gravel removal to OWR in the statute).

39. VT. STAT. ANN. tit. 10, § 1002.

focused new Clean Water Act ("CWA") Section 319 funding[40] on land-based pollution treatments favoring "green" over "gray" structural stream controls. Nonpoint source programs, including wetland and stream buffer protection programs, recognized that real progress in restoring the physical, chemical, and biological integrity of our waters would occur with the acceptance that land use and land cover changes would be needed.[41] Vermont connected the final dots after a series of devastating floods in the 1990s prompted the Vermont General Assembly to pass Act 137, calling for "a flood control program that balances the need to protect the environment with the need to protect public and private property."[42]

In 1998, the Rivers Program was formed by combining the Stream Alteration and (Section 319) Stream Restoration programs.[43] This pivotal connection of river and riparian lands management in Vermont came about at the time when water resource professionals throughout the nation were flocking to training courses on fluvial geomorphology. The Rivers Program participated and brought this science home where it served as an organizing principle for the new Vermont program.[44] Its first policy initiative was crafted in the Act 137 report to the Legislature wherein riverine erosion was established as Vermont's primary flood-related hazard (over inundation) and called on Vermont agencies and municipalities to account for both the instream and land-based activities that were causing streams to become more highly erosive (geomorphically unstable).[45]

One year later, the floodplain program that administered the National Flood Insurance Program was folded into the Rivers Program.[46] Under new management, DEC began defining "floodways" in Act 250 cases to include both the FEMA-defined floodway and fluvial erosion hazard ("FEH") areas.[47] This controversial break with traditional floodplain management resulted in a landmark decision in the *Woodford Packer* case, which put

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40. 33 U.S.C. § 1329 (2016) (statute show funding for point sources that are land-based).

41. U.S. ENVTL. PROT. AGENCY, *Types of Nonpoint Source*, https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/types-nonpoint-source [https://perma.cc/F4X2-DMMP] (last updated Oct. 31, 2015).

42. 1998 Vt. Acts & Resolves 137 (codified as amended at VT. STAT. ANN. tit. 10, § 905b(3) (1998)).

43. *Rivers Program*, *supra* note 29 (providing a description of the responsibilities of the Rivers Program after combining other state programs).

44. *Geomorphic Assessment*, VT. DEP'T OF ENVTL. CONSERVATION, http://dec.vermont.gov/watershed/rivers/river-corridor-and-floodplain-protection/geomorphic-assessment [https://perma.cc/MKX7-WR62] (last visited Apr. 4, 2016).

45. VT. AGENCY OF NAT. RES., OPTIONS FOR STATE FLOOD CONTROL POLICIES AND A FLOOD CONTROL PROGRAM 4, 16 (1999), http://docplayer.net/1243241-Options-for-state-flood-control-policies-and-a-flood-control-program.html [https://perma.cc/JEA8-GUJX].

46. *Rivers Program*, *supra* note 29.

47. *In re* Woodford Packers, Inc., 830 A.2d 100, 106 (Vt. 2003).

Vermont in the vanguard of establishing fluvial geomorphic-based procedures for regulating developments to avoid FEH.[48]

As this case was unfolding, the 2002 Lake Champlain TMDL was prepared by the Water Quality Division and the new Rivers Program posited that University of Vermont phosphorus loading studies[49] had missed a key source of the nutrient: unstable streams. The argument lacked empirical data, but it was based on sound science and was, therefore, included along with a robust budget to carry out river and floodplain restoration projects.[50] When Governor Douglas took office in 2003, he announced the cleanup of Lake Champlain as the main component of his environmental agenda and the Legislature followed suit by allocating funds identified in the new TMDL.[51] With new staff, operating funds, and an annual million dollar budget to support a grants program for the purpose of restoring stream equilibrium, the Rivers Program was off and running.

These formative years of the Program included a string of fortunate events, including the near-complete failure of its flagship Trout River Restoration Project in Montgomery, Vermont.[52] Fortune from failure is accurate because, over a three-year period, the Program devoted nearly all of its resources toward major river restoration projects under the premise that the state could engineer and construct the desired stream equilibrium conditions on a reach-by-reach basis.[53] But even streams with an idealized geometry are dynamic and watching the next flood erase beautifully constructed meanders was a powerful message that rivers in Vermont were adjusting and equilibrating at scales much greater than the scope of the projects. We also witnessed that during the years spent restoring one mile of river, new encroachments were occurring along many miles of river that would force the state to keep more rivers channelized over time.[54] This

48. *Id.* at 102–04.

49. U.S. ENVTL. PROT. AGENCY, PHOSPHORUS TMDLS FOR VERMONT SEGMENTS OF LAKE CHAMPLAIN 19 (2015), http://winooskinrcd.org/wp-content/uploads/phosphorus-tmdls-vermont-segments-lake-champlain.pdf [https://perma.cc/7GW8-5U57]; *see* Joshua E. Brown, *Stream Study Raises New Questions About Lake Pollution*, U. OF VT. (Nov. 11, 2015), http://www.uvm.edu/~uvmpr/?Page=news&storyID=21802 [https://perma.cc/65GH-Z3GR] (demonstrating that UVM studies on phosphorus loading do not point to unstable streams as a source).

50. U.S. ENVTL. PROT. AGENCY, *supra* note 49, at 16.

51. VT. AGENCY OF NAT. RES. & N.Y. STATE DEP'T OF ENVTL. CONSERVATION, LAKE CHAMPLAIN PHOSPHOROUS TMDL (2002), http://www.dec.ny.gov/docs/water_pdf/champlain_final_tmdl.pdf [https://perma.cc/U4QY-89UV].

52. *The Trout River*, LAKE CHAMPLAIN BASIN PROGRAM, http://www.lcbp.org/Champlain2000/c2k/troutr.htm [https://perma.cc/5C5S-E2Y9] (last updated June 5, 2000) (providing a status report on the Trout River project).

53. KLINE, *supra* note 6, at 13.

54. *The Trout River*, *supra* note 52, at 6.

lose-lose situation prompted the Rivers Program to put the brakes on future large-scale channel restorations.

In the "lessons learned" category of the Trout River Project, we also made note that when the floods receded in Montgomery, no one rushed in with yellow machines to put things back the way they were. The most successful aspect of the Project was that a corridor of land encompassing the constructed meanders had been protected through landowner agreements.[55] Within just a couple of years, the Trout River, free to move, was forming its own brand of dynamic equilibrium.[56] From this lesson, river corridor protection became the Program's primary objective.

What began in 2003 would be the work of generations of Vermont river managers: getting Vermonters to embrace an "avoidance approach"; giving rivers the room to move; and managing toward natural dynamic equilibrium conditions and the natural processes that will minimize erosion over time. Changing the centuries-old paradigm that the only safe and productive river was a structurally managed river would take compelling place-based river stories supported by data that could explain the benefit and cost of a passive versus active restoration program.

2. Creating a Constituency—Funding, Outreach, and Technical Assistance

A new river management paradigm has come about in Vermont due to the ever-broadening application of practices based on fluvial geomorphic principles. When the 2002 Lake Champlain TMDL was being adopted, the Rivers Program pulled in many collaborating agencies to help develop a stream geomorphic assessment ("SGA") program with a scientifically sound data collection protocol;[57] a web-based data and mapping system accessible to all users;[58] and a method for predicting stream channel and floodplain evolution that technically supports the resolution of river and land use conflicts.[59] We had to create an assessment methodology that would help lay people understand how human activities and sound land use

55. KLINE, *supra* note 6, at 84.

56. *The Trout River*, *supra* note 52, at 10.

57. *Stream Geomorphic Assessment Protocol*, VT. AGENCY OF NAT. RES., https://anrweb.vt.gov/DEC/SGA/instructions/protocol.aspx [https://perma.cc/LGT7-6XQE] (last visited Apr. 3, 2016).

58. VT. AGENCY OF NAT. RES., STREAM GEOMORPHIC ASSESSMENT BRIDGE AND CULVERT DATA MANAGEMENT MANUAL 1 (2008), http://dec.vermont.gov/sites/dec/files/wsm/rivers/docs/rv_SGAB%26CDataManagementManual2008.pdf [https://perma.cc/9K5S-7LB8].

59. VT. AGENCY OF NAT. RES., STREAM GEOMORPHIC ASSESSMENT PROGRAM INTRODUCTION 2, http://dec.vermont.gov/sites/dec/files/wsm/rivers/docs/rv_geomorphassess.pdf [https://perma.cc/QJ2T-D57P] (last visited Apr. 3, 2016).

practices can be conducted in a manner that is both ecologically and economically sustainable. Water resource planners and practitioners have increasingly accepted working at much greater spatial and temporal scales than they might have otherwise thought prudent because they participated in the underlying science.

Essential to the success of the SGA program was making sure that, in a world where changes in land use and land cover are largely voluntary, the data must be obtained by collaborators and people close to the land. In other words, the data could not be collected and "owned" solely by a group of state scientists. The data had to be the property of those who would create and share "stories of the river," explaining why new and different actions were important. To incentivize local ownership of these river stories, the Rivers Program established that TMDL river restoration funds would be made available as grants to watershed organizations and municipalities for restoration and protection projects identified in River Corridor Plans[60] based on stream geomorphic data collected using the ANR protocols. Supporting on-the-ground projects only if they were based on sound, replicable science created a "gold rush" toward the assessment of stream geomorphology in Vermont.[61]

To date, the citizens of Vermont, their cadre of ANR-trained river science consultants, and many partner agencies and organizations have collected and quality-assured over 8,000 river miles of Phase 1 (remote sensing) geomorphic data and over 2,100 river miles of Phase 2 (field collected) geomorphic data to prepare more than 100 river corridor plans.[62] Each year since 2004, the agency and its partners have funded at least two dozen river restoration and protection projects identified and prioritized in the river corridor planning process.[63] All of the data and plans are available online and geo-referenced in the ANR Natural Resource Mapping Atlas.[64]

In 2006, the Rivers Program began purchasing river flumes (metal trays with water flowing through a sand-like medium) that allow people to watch firsthand how rivers work at a miniaturized scale. With freshly-minted river corridor plans, the conservation districts and watershed groups have

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60. KLINE, *supra* note 6, at 12.

61. *Id.* at 14 ("The State's goal of managing toward stream equilibrium condition is often compatible with more localized goals.").

62. VT. DEP'T OF ENVTL. CONSERVATION, STREAM GEOMORPHIC ASSESSMENT - FINAL REPORTS, https://anrweb.vt.gov/DEC/SGA/finalReports.aspx [https://perma.cc/YRD3-H2BD] (last visited Apr. 20, 2016).

63. *River Corridor Planning, Protection, and Restoration*, VT. DEP'T OF ENVTL. CONSERVATION, http://dec.vermont.gov/watershed/rivers/river-corridor-and-floodplain-protection/river-corridor-planning-and-protection [https://perma.cc/VX3V-DY6M] (last visited May 11, 2016).

64. VT. AGENCY OF NAT. RES., *Natural Resources Atlas*, http://anrmaps.vermont.gov/websites/anra/ [https://perma.cc/T5G4-YT4X] (last visited Apr. 4, 2016).

sponsored local gatherings to serve up the science with cookies and cider, telling the "river story," and using hands-on experiments at the flume to convince town officials and landowners to work with them outside their dredge and armor comfort zone. It has been a beautiful demonstration of applied folk science.

While groups were explaining the condition of their local river, the Rivers Program was using all the data to impress state policymakers and program managers. As more and more agencies gained an appreciation for how geomorphically stable streams and natural functioning floodplains would serve their missions (such as clean water, fish habitat, soil conservation, property and infrastructure protection, hazard mitigation, and economic resiliency), they too began creating funding incentives and technical assistance for projects and protections identified in river corridor plans. This translated into new statutes and the regulatory approaches as described below.

3. Statutory Changes and Rulemaking

By 2007, the TMDL funding originally allocated for river restoration grants was moved to the ANR Secretary's office to help start a Clean and Clear Program charged with addressing a much broader set of nutrient sources. With assistance from EPA and the Lake Champlain Basin Program, Clean and Clear placed a greater emphasis on gaining knowledge and supporting farm and urban stormwater management practices.[65] Field trips to farms revealed miles of ditches, in both field and stream, with no buffers filtering the surface runoff from ever-expanding row crops. During the debate over buffers on ditched streams, the anecdote was shared that a farmer would rather culvert streams underground than give up cropland to meet buffer requirements. This thinking helped to align political forces advocating greater state jurisdiction of small streams and riparian buffers.

The 2010 General Assembly passed Act 110, which erased the ten square mile jurisdictional threshold in the state regulation of stream alterations.[66] Changing the course, current, or cross-section of any perennial stream by the excavation or fill of ten cubic yards of material now required a permit.[67] Prohibiting adverse effects to public safety from fluvial erosion

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65. VT. AGENCY OF NAT. RES., VERMONT CLEAN AND CLEAR ACTION PLAN 1 (2009), http://www.wwwalker.net/champ/tmdl/references/VT%20Clean%20and%20Clear%20Annual%20Report%20(2009).pdf [https://perma.cc/9QXN-E4GD].

66. DEP'T OF ENVTL. CONSERVATION, VT. AGENCY OF NAT. RES. ACT 110 STREAM ALTERATION REPORT TO THE VERMONT GENERAL ASSEMBLY 1 (2011), http://www.leg.state.vt.us/reports/2011externalreports/265340.pdf [https://perma.cc/FK4M-DATW].

67. *Id.*

hazards was also added to the criteria for stream alteration permitting.[68] Farmers who might contemplate the piping of small streams under their fields would now need a state permit to do so.[69]

Act 110 started out as a buffer bill. It was the intent of the bill to require all riparian landowners to establish and maintain a twenty-five- to fifty-foot vegetative buffer on all streams.[70] The Rivers Program came out against the buffer provisions.[71] The committee room became a classroom featuring a short course on fluvial geomorphology. The Program eventually convinced representatives that requiring a buffer may establish the desired vegetation, but it would also establish a setback standard for new encroachments; a twenty-five- or even fifty-foot setback on streams, if strictly observed, would be to the detriment of larger streams that need hundreds of feet to complete the channel evolution process.[72] Streams and rivers that were historically straightened would be locked into a channelization condition, i.e., managed as shaded ditches.[73] Any buffer-related water quality and habitat gains would be eroded away during floods when the river widened through stages III and IV of the channel evolution process (Figure 2), or further deepened from being pushed back to stage II with bank stabilization practices employed to save the required buffer.[74] The Committee went on to embrace the river corridor concept. Vermont became the first state to include the protection of stream equilibrium as public policy in state statute.[75] Act 110 solidified ANR's practice of using river corridors to define the protected floodway in Act 250 land use cases[76] and provided a mandate for creating municipal incentives to strengthen local river corridor protections.

The next leap forward came in the aftermath of Tropical Storm Irene in August of 2011. The 2012 General Assembly came together with resolve to

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68. *Id.* at 3.

69. VT. STAT. ANN. tit. 10, §§ 1002(10), 1022.

70. *Id.*

71. Mike Kline & Kari Dolan, VERMONT AGENCY OF NATURAL RESOURCES RIVER CORRIDOR PROTECTION GUIDE: FLUVIAL GEOMORPHIC-BASED METHODOLOGY TO REDUCE FLOOD HAZARDS AND PROTECT WATER QUALITY 4–5 (2008), http://dec.vermont.gov/sites/dec/files/wsm/rivers/docs/rv_RiverCorridorProtectionGuide.pdf [https://perma.cc/AC6P-EQYY] [hereinafter RIVER CORRIDOR PROTECTION GUIDE].

72. *See* STREAM GEOMORPHIC ASSESSMENT PROGRAM INTRODUCTION, *supra* note 59, at 6 (describing the Program's stream geomorphic classification assessment tool).

73. RIVER CORRIDOR PROTECTION GUIDE, *supra* note 71.

74. *See id.* (explaining that flooding often creates loss of vegetation and further erosion).

75. VERMONT NATURAL RESOURCES COUNCIL, READING VERMONT'S RIVERS (2013), http://vnrc.org/wp-content/uploads/2013/07/Reading-Rivers-reduced.pdf [https://perma.cc/8FQ3-V5LP].

76. 2010 Vt. Acts & Resolves 110 (codified at or as amended at VT. STAT. ANN. tit. 10, §§ 1422(12), 1427(b) (2010)).

address shortcomings in state jurisdiction over post-flood, instream "recovery" work and the lack of adequate floodplain protections.[77] Act 138, the Rivers Bill, mandated several transformations in the Rivers Program.[78] In addition to a call for training programs to teach stream equilibrium concepts to highway workers, the Bill requires the adoption of two sets of state rules: one governing stream alterations, including emergency protective measures as conducted by municipalities; and a second governing land use activities exempt from municipal regulation for the protection of flood hazard areas.[79] The river corridor planning and protection provisions established by Act 110 were also revised and strengthened.[80]

In 2013 and 2014 the Legislature passed Acts 16 and 107, which mandated the inclusion of flood resiliency chapters in town plans and authorized ANR to include river corridor protections in the new state floodplain rules.[81] The above mentioned statutes collectively recognize the vital importance of functioning floodplains and river corridors in managing streams toward a naturally stable, least erosive form (i.e., equilibrium condition).

B. Managing Toward Stream Equilibrium

1. Creating an Integrated Set of Standards

Rulemaking provided the opportunity to tighten the stitches between Vermont's river, river corridor, and floodplain management programs and to demonstrate that vertical stream channel stability and floodplain function are two sides of the same coin. The new rules establish a set of performance-based standards for stream equilibrium, connectivity, and river corridor protection, all of which promote the fluvial processes that connect rivers and floodplains as one functioning riparian system.

The Vermont Stream Alteration Rule establishes that non-emergency actions shall not change the physical integrity of the stream in a manner that causes it to depart from, further depart from, or impedes the attainment of stream equilibrium conditions by resulting in an unnatural aggrading or

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77. VT. DEP'T OF ENVTL. CONSERVATION, SUMMARY OF "RIVERS BILL" COMPONENTS OF ACT 138 1 (2012).

78. VT. STAT. ANN. tit. 10, § 1421.

79. SUMMARY OF "RIVERS BILL" COMPONENTS OF ACT 138, *supra* note 77, at 2.

80. *Id.*

81. VT. STAT. ANN. tit. 24 § 4302 (2016); 2014 VT. ACTS & RESOLVES 107 (codified as amended Vt. Stat. Ann tit. 10, § 754(a).

degrading of the stream channel bed.[82] Activities shall not alter the flow patterns, natural streambank stability, or floodplain connectivity in a manner that: a) results in localized, abrupt changes to the alignment of streambanks or profile of the stream bed; or (b) creates a physical obstruction or velocity barrier to the movement of aquatic organisms.[83] No longer are people permitted to construct or maintain a berm in a floodplain or river corridor unless it is authorized as an emergency protective measure.[84]

On the land use side of the equation, development under state jurisdiction (e.g., decisions rendered under Act 250 Criterion 1(D)) must be sited outside of the river corridor to ensure there is no increase in fluvial erosion hazards by constraining the river and causing it to depart from, or further depart from, equilibrium conditions.[85] Exceptions are made for stream crossings, infill, and redevelopment.[86] DEC applies a performance standard to ensure that if development is approved, it will not result in the need for any new stream channelization that would alter the flow and sediment dynamics of the stream, triggering channel adjustments and erosion in adjacent and downstream locations.[87]

These precedent-setting standards recognize that natural floodplain function depends on sound river management. They work to achieve a geomorphically stable and ecologically functioning river, which depends on the erosion and deposition processes in a meander belt and riparian buffer system unconstrained by human activity.[88] The standards implement Vermont's anti-degradation policy, recognizing equilibrium conditions as supporting high quality waters and a broad set of beneficial surface water uses and values.[89] ANR protects the fluvial processes—and the resulting channel adjustments driving channel evolution—as necessary to guard

82. VT. AGENCY OF NAT. RES., VERMONT STREAM ALTERATION RULE 9, http://dec.vermont.gov/sites/dec/files/documents/WSMD_StreamAlterationRule_2013_12_24.pdf [https://perma.cc/6BJB-RVVH] (last visited July 2, 2016).

83. *Id*. at 10.

84. *Id*. at 8.

85. DEP'T OF ENVTL. CONSERVATION, VT. AGENCY OF NAT. RES., FLOOD HAZARD AREA AND RIVER CORRIDOR PROTECTION PROCEDURE 20 (2014), http://dec.vermont.gov/sites/dec/files/documents/dec-fharcp-2014-12-5.pdf [https://perma.cc/VFD9-B7LA] (unless the proposal satisfies "No adverse impact standard").

86. *Id.* at 21–22.

87. *Id.* at 22.

88. *Id.* at 25; MILONE & MACBROOM, INC., FITZGERALD ENVIRONMENTAL ASSOCIATES, LLC & VT. AGENCY OF NAT. RES., VERMONT STANDARD RIVER MANAGEMENT PRINCIPLES AND PRACTICES: GUIDANCE FOR MANAGING VERMONT'S RIVERS BASED ON CHANNEL AND FLOODPLAIN FUNCTION (2015), http://dec.vermont.gov/sites/dec/files/documents/wsmd-rv-standard-river-management-principles-practices-2015-06-12.pdf [https://perma.cc/6465-QRUN].

89. FLOOD HAZARD AREA AND RIVER CORRIDOR PROTECTION PROCEDURE, *supra* note 85, at 25.

against backsliding to disequilibrium stages in which increases in sediment and nutrient runoff into streams, rivers, and ultimately Lake Champlain, would be expected.[90]

2. Restoring Floodplains with Standard River Management Principles and Practices

The solution to excessive streambank and channel erosion is managing toward stream equilibrium. Activities should not alter a stream in a manner that decreases its power to transport sediment, causing it to aggrade (or fill in), or increases its power so much that the channel bed erodes.[91] The central principle is to protect and restore components of channel and floodplain geometry to more evenly distribute stream power (energy) and maximize overall vertical stability.[92]

Finding opportunities to restore channel and floodplain geometry and achieve equilibrium in Vermont's straightened streams would be challenging even in a perfect world where there were no human constraints. But after a flood, protecting buildings, roads, and utilities is a legal right and we are only beginning to weigh the rights of others to the accrued benefit of functioning floodplains. What changed in the aftermath of Irene is that, while municipalities may continue to dredge and fill streams to address imminent threats to public safety and property without prior authorization from the state, in-stream work must be conducted in accordance with state rules to avoid unnecessary stream and floodplain impacts.

In tandem with adopting rules for both emergency and non-emergency in-stream measures, the Vermont Rivers Program contracted the development of Standard River Management Principles and Practices.[93] This manual describes specific designs and methods for managing toward equilibrium conditions and provides the basis for training the road and utility workers on how to avoid making streams less stable when dredging and filling to address severe post-flood damage.[94] Training flood responders and adopting rules to ensure compliance is a critical component of the Lake Champlain TMDL Implementation Plan.

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90. *Id.*
91. KLINE, *supra* note 6, at 30.
92. *Id*.
93. VERMONT STANDARD RIVER MANAGEMENT PRINCIPLES AND PRACTICES, *supra* note 88.
94. *Id.* at 177.

In addition to efforts aimed at decreasing the extent and severity of stream disequilibrium caused by ill-advised post-flood channelization, Vermont is using state and federal funding to promote active restoration of floodplains.[95] Occasionally, there are opportunities to excavate a sufficiently wide new floodplain (i.e., bring the floodplain down to the stream). More often, we elevate the stream so that the annual flood will be able to spill out onto the old floodplain feature that became abandoned when the stream incised. Even more common are the projects to create smaller floodplain benches during streambank stabilization projects along roadways.

Active floodplain restoration is far less costly than in-channel restoration and addresses the erosion caused by an over-deepening of flood flows.[96] Once a stream is reconnected to a floodplain, it becomes more depositional. Coarse sediments deposit in the channel and begin forming meanders. Flood waters, now slowing on the floodplain, drop significant quantities of fine sediment and nutrient. A project involving the removal of six miles of rail levee along the Black Creek and Lamoille River in Vermont reconnected 200 acres of floodplain.[97] In a one-year period covering two flood cycles, measurements were made of the fine sediment and phosphorus that deposited on four of the reconnected sites (representing ten percent of the total reconnected floodplain).[98] The state's consultants found that 950 cubic yards of sediment and 1.3 metric tons of phosphorus were deposited and stored on the now-functioning Lamoille River floodplains.[99]

95. VT. DEP'T OF ENVTL. CONSERVATION, RIVER, RIVER CORRIDOR, & FLOODPLAIN MANAGEMENT PROGRAMS 7 (2013) http://www.leg.state.vt.us/reports/2013ExternalReports/285582.pdf [https://perma.cc/6CYX-NSP9].

96. KLINE, *supra* note 6, at 50.

97. ROY SCHIFF, BARRY CAHOON, & MIKE KLINE, BLACK CREEK AND LAMOILL RIVER FLOODPLAIN RESTORATION PROJECT, http://dec.vermont.gov/sites/dec/files/wsm/rivers/docs/LVRT_RMS.pdf [https://perma.cc/E6YH-XAEA] (last visited July 1, 2016).

98. *Id.* at 96.

99. VT. DEP'T OF ENVTL. CONSERVATION, STATE OF VERMONT: 2010 WATER QUALITY INTEGRATED ASSESSMENT REPORT 101 (2010) http://dec.vermont.gov/sites/dec/files/documents/WSMD_mapp_305b%20WQ%20Report_2010.pdf [https://perma.cc/7CQ6-N2HV].

C. Focus on Avoidance

1. The River Corridor

The alternatives for addressing excessive channel erosion are to: (a) manage it with hard armor; (b) hasten the evolution process with restoration practices; or (c) limit channel and floodplain encroachments so that the evolution process can proceed unimpeded to an equilibrium state.[100] Hard armoring is often the only choice along the roads and villages of Vermont, but this often shunts erosion to downstream reaches.[101] If one considers private landownership, the number of incised channels, and the limits of time and money, one may reasonably conclude that Vermont will only achieve the objective of watershed-wide equilibrium if encroachments are limited and floods are not impeded from creating stream meanders and floodplains. The question is "how much room does the river need"?

A river requires sufficient room to accommodate equilibrium conditions and the channel adjustments that occur when channel geometry is changing vertically and laterally to achieve equilibrium.[102] Smith et al. suggest the "Active River Area" be set aside, which is essentially the entire valley floor.[103] Several western states use "Channel Migration Zones."[104] Vermont defines a "river corridor" to include the existing or calculated meander belt of the

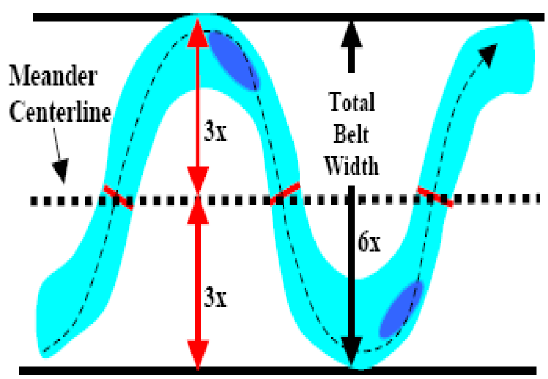

Figure 3: Depiction of meander centerline and belt width delineation.

100. VT. DEP'T OF ENVTL. CONSERVATION, CHANNEL EROSION http://dec.vermont.gov/sites/dec/files/documents/WSMD_swms_StressorPlan_Channel%20Erosion_Web_V3.pdf [https://perma.cc/Q5VR-HCB7] (last visited July 9, 2016).

101. U.S. FED. EMERGENCY MGMT. AGENCY, ENGINEERING WITH NATURE: ALTERNATIVE TECHNIQUES TO RIPRAP BANK STABILIZATION 8, https://www.fema.gov/pdf/about/regions/regionx/Engineering_With_Nature_Web.pdf [https://perma.cc/4KCG-DPXE] (last visited Apr. 3, 2016).

102. *River Corridors*, VT. FLOOD READY, http://floodready.vermont.gov/flood_protection/river_corridors_floodplains/river_corridors [https://perma.cc/KQE9-Y7QM] (last visited Apr. 1, 2016).

103. SMITH ET AL., *supra* note 7.

104. *See* CYNTHIA F. RAPP & TIMOTHY A. ABBE, A FRAMEWORK FOR DELINEATING CHANNEL MIGRATION ZONES (2003), https://fortress.wa.gov/ecy/publications/publications/0306027.pdf [https://perma.cc/7BDK-DQLK] (providing details on channel mitigation zones).

river at a least erosive, equilibrium slope and depth.

The meander belt extends laterally across the river valley from each of the outermost meander bends, thereby encompassing the natural planform variability of the stream channel (Figure 3), which maintains the equilibrium slope and minimizes vertical channel instability over time.[105] If the river has been straightened, the natural meander belt may not be discernable. In this case the river corridor is modeled by calculating the width of the meander belt as a multiple of the bankfull channel width.[106] Figure 3 depicts the use of a meander centerline to split a meander belt width modeled as six times the channel width, with three channel widths allocated to either side of the centerline. The Vermont Flood Hazard Area and River Corridor Protection Procedures provide further detail on the river corridor delineation process.[107]

Thus, managing a river corridor to accommodate equilibrium and associated channel adjustment processes will serve to reduce damages to existing structures and property, avoid new damages, protect public safety, achieve the general health of the river system (including sediment and nutrient load reductions), and avoid the high cost to install and maintain channelization practices.[108] Precluding the use of channelization practices, in turn, avoids the unintended consequences of transferring bank erosion and other damaging effects from concentrated flow and vertical channel adjustments to other locations along the river.[109]

The Vermont General Assembly specifically called for the inclusion of buffers within the river corridor.[110] Therefore, river corridors are defined and mapped with an additional fifty-foot setback on either side of the meander belt as a margin of safety and to allow space for the maintenance of a vegetated buffer throughout the channel evolution process, including the final evolution stage when the meanders are extended to the edge of the meander belt.[111] A vegetated buffer provides a host of ecosystem services,

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105. ANN L. RILEY, RESTORING STREAMS IN CITIES: A GUIDE FOR PLANNERS, POLICYMAKERS AND CITIZENS (1998).

106. Garnett P. Williams, *River Meanders and Channel Size*, 88 J. HYDROLOGY 147, 150 (1986).

107. VT. AGENCY OF NAT. RES., FLOOD HAZARD RIVER AND RIVER CORRIDOR PROTECTION PROCEDURE, 33 (2014), http://dec.vermont.gov/sites/dec/files/documents/dec-fharcp-2014-12-5.pdf [https://perma.cc/3QBM-UMTF].

108. *River Corridors*, *supra* note 102.

109. VT. AGENCY OF NAT. RES., FLOOD HAZARD AREA AND RIVER CORRIDOR PROTECTION PROCEDURE (2014) (unpublished draft), http://floodready.vermont.gov/sites/floodready/files/documents/2014-10-06%20%20Final%20Draft%20Flood%20Hazard%20Area%20and%20River%20Corridor%20Protection%20Procedures.pdf [https://perma.cc/CK9C-USWG].

110. VT. STAT. ANN. tit. 10, § 1422(12).

111. KLINE, *supra* note 6, at 66.

but in the case of the river corridor, they are established for their value in streambank stability and slowing flood water velocities in the near-bank region.[112] Vegetated buffers are a least-cost, self-maintaining practice, which provide natural boundary conditions and streambank resistance against erosion and moderate lateral channel migration.[113]

Vermont's plan for implementing the TMDL includes a commitment to address the loading from streambank and channel erosion by increasing nutrient storage on functioning floodplains primarily through river corridor protection.[114] With seventy-five percent of Vermont stream channels moderately to severely incised, the potential for restoring floodplain storage is great—if we stay out of the way to let floodplains naturally reform. Vermont must work to avoid new encroachments and make every effort to identify and remove non-essential structures that are impeding channel evolution.

2. Regulatory Solutions at the State and Municipal Level

The most effective way to limit encroachments in river corridors and floodplains is to avoid them in the first place. Increased regulation by the state and by municipalities is occurring in response to an increased public awareness of the safety risks and property damage from floods. Water quality improvement is not used to start the conversation about new local land use regulations, but is acknowledged as a benefit.

The State Flood Hazard Area and River Corridor Rule limits new encroachments that are exempt from municipal regulation, including state buildings, state transportation infrastructure, farm and logging-related developments, and utilities regulated by the Public Service Board under section 248.[115] The DEC Flood Hazard Area and River Corridor Protection Procedures mirror the rule in applying the No Adverse Impact standard to land use activities regulated by the state under Act 250 Criterion 1(D).[116] This leaves one major land use regulatory arena where the state plays only an advisory role—river corridor and floodplain development that is sub-jurisdictional in Act 250 and, therefore, only regulated by a municipality.[117]

Municipalities that have adopted flood hazard area or river corridor bylaws are required to submit permit applications for flood hazard area and

112. *Id.* at 66–67.
113. *Id.* at 67.
114. *Id.* at 87.
115. FLOOD HAZARD AREA AND RIVER CORRIDOR PROTECTION PROCEDURE, *supra* note 111, at 3–4.
116. *Id.* at 21.
117. *Id.* at 3.

river corridor development to DEC for review and comment pursuant to 24 V.S.A. § 4424(a)(2)(D).[118] The Rivers Program reviews applications for completeness and then evaluates the development proposal against the effective flood hazard area and/or river corridor map in conjunction with the standards adopted by the municipality (a vast majority of which are the minimum standards required by FEMA for enrollment in the NFIP).[119] The Program provides written comments and recommended permit conditions with regard to any aspect of the proposal not in compliance with the municipal bylaw.[120] The data below was gathered in preparing the 2015 Rivers Program's Results-Based Accountability report to the legislature and is offered here to illustrate the relative number of projects reviewed under the three above-mentioned jurisdictions.

ANR Permitted Floodplain and River Corridor Projects	63
Act 250 Floodway Determinations to Protect Floodplains and River Corridors	65
Municipally Permitted Floodplain and River Corridor Projects	845

The compliance of municipalities with the state review requirement is estimated to be in the thirty- to fifty-percent range.[121] To help address this lack of participation, the legislature established the Flood Resilient Communities Program to increase funding incentives for municipalities that have adopted river corridor and floodplain protections.[122] A number of incentives have been established, but the most significant to date has been the 2013 amendments to the rules governing the Emergency Relief and Assistance Fund ("ERAF"), which helps the municipality meet the federal twenty-five percent match requirements under FEMA flood recovery programs.[123]

Towns that have adopted river corridor protection bylaws would see the percentage split of the federal match between the town and state change in

118. VT. STAT. ANN. tit. 24, § 4424(a)(2)(D) (2015).

119. FLOOD HAZARD AREA AND RIVER CORRIDOR PROTECTION PROCEDURE, *supra* note 109, at 24, 26.

120. *Id.* at 5.

121. Author's personal knowledge.

122. VT. STAT. ANN. tit., 10 § 1428.

123. *Emergency Relief and Assistance Fund*, VT. FLOOD READY, http://floodready.vermont.gov/find_funding/emergency_relief_assistance [https://perma.cc/7C4R-W8TD] (last visited Apr. 12, 2016).

their favor: from a fifty-fifty split to a twenty-five to seventy-five split.[124] For instance, if a town experiences one million dollars in damages, FEMA Public Assistance Program would pay $750,000; the state share would increase from $125,000 to $187,500 if the municipality has a river corridor bylaw or its equivalent in place.

By the end of 2015, there were 35 Vermont municipalities (out of 251) that had adopted river corridor maps and zoning bylaws.[125] Over a dozen other communities were in the process of considering or adopting river corridor protections, primarily because of the ERAF incentive.[126] However, EPA and the state are hearing concern by some (expressed as comments on the draft TMDL) that this progress is too slow.[127] It is said that leaving the regulation of encroachment to the discretion of municipalities may not realize the targeted reductions from the restoration of floodplain and equilibrium conditions within any reasonable timeframe, if ever.

3. Conservation Easements

Streambank stabilization is a part of the state rule governing agricultural practice that is promulgated to protect water quality on farms.[128] This means that if farmers in Vermont want to stabilize a streambank, they may do so without a permit from ANR as long as they do not cause a fluvial erosion hazard. Although this exception in the stream alteration statute means ANR is limited in its governance of a major channel erosion stressor, many farmers turn to state and federal agencies (including river management engineers with the DEC Rivers Program) or technical and financial assistance when they seek to establish or maintain rip-rap on a streambank.

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124. *Id.*

125. MIKE KLINE, FUNCTIONING RIVER AND FLOODPLAIN SYSTEMS: VERMONT'S MANAGEMENT STANDARD (2015) http://floodready.vermont.gov/sites/floodready/files/documents/Functioning%20River%20and%20Floodplain%20Systems--Vermont%E2%80%99s%20Management%20Standard.pdf [https://perma.cc/XZ85-SD3K].

126. VT. DEP'T OF ENVTL. CONSERVATION, RIVER CORRIDOR AND FLOODPLAIN MANAGEMENT PROGRAM AND SHORELAND PROTECTION PROGRAM 3 (2015), http://legislature.vermont.gov/assets/Legislative-Reports/2014-Act-110-LegReport-January-2015.pdf [https://perma.cc/C74L-MERE].

127. Letter from Karen B. Horn, Dir., Pub. Policy & Advocacy Dep't, Vt. League of Cities & Towns to Stephen Perkins, Lake Champlain TMDL Project Manager, U.S. Envtl. Prot. Agency, Region 1 (Oct. 15, 2015), http://www.vlct.org/assets/Advocacy/vlct_testimony/2015-10-15_lake_champlain_tmdl_comments.pdf [https://perma.cc/L2L2-ASE4].

128. VT. AGENCY OF AGRIC., FOOD & MKTS., REQUIRED AGRICULTURAL PRACTICES REGULATIONS FOR THE AGRICULTURAL NON-POINT SOURCE POLLUTION CONTROL PROGRAM 7, http://agriculture.vermont.gov/sites/ag/files/pdf/water_quality/VAAFM-Draft-RAP.pdf [https://perma.cc/HWF3-36FH].

This point of contact gives ANR and its partners the opportunity to discuss conservation as an alternative to the furtherance of channelization practice, particularly on reaches identified in a river corridor plan as being a high priority for a river corridor easement. Along reaches that are high sediment deposition zones—where the farm family has struggled to control a very dynamic stream for a very long time—the idea of being paid for an easement rather than paying out for a rip-rap installation has become attractive to some farmers. The river corridor easement is a unique conservation tool that has increasingly become a key component of DEC's plan for restoring floodplain function and nutrient storage.[129]

Land use regulation and traditional conservation tools may be effective in limiting new encroachments, but they do not limit riparian landowners from structurally controlling the streams on their land.[130] The river corridor easement is used separately or in conjunction with other conservation tools to purchase the channel management rights in the meander belt of the stream.[131] The farmer must leave an open buffer along the river, but may otherwise continue to farm in the corridor as a "guest of the river." They have sold their right to change the course, current, or cross-section of the stream or impede the channel evolution process.

The specifics and rationale for the Vermont river corridor easement are presented on DEC's River Program web page.[132] By the end of 2015, the Rivers Program and its conservation partners executed over sixty river corridor easements on rivers identified as key flood flow and sediment attenuation assets.[133] These are reaches where the river is rated as highly sensitive where floodplain function is likely to return sooner rather than later.

4. Other Incentives and Agency Collaborations

The Rivers Program might perfect its technical, regulatory, and funding assistance tools, but if it were addressing streambank and channel erosion on its own, only a fraction of the activities driving stream instability would be addressed. Vermont is making significant progress because of the

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129. MIKE KLINE, A GUIDE TO RIVER CORRIDOR EASEMENT 1 (2010), http://dec.vermont.gov/sites/dec/files/wsm/rivers/docs/rv_RiverCorridorEasementGuide.pdf [https://perma.cc/FL9H-MPZL].

130. *See id.* at 7 (explaining that riparian restoration and protection goals can be achieved with river corridor easements).

131. Kline & Cahoon, *supra* note 5, at 7.

132. *Rivers Program*, *supra* note 29.

133. *Id.* (navigating the website of the Rivers Program shows that vast amount of corridor easements and flood flow areas).

funding incentives, siting restrictions, and technical assistance established within other programs and agencies. It would now be the exception to find a state or federal agency in Vermont with an interest in water quality or flood hazard mitigation that does not work with its constituency to stay out of river corridors, avoid stream channelization, and promote floodplain protection and restoration. The following are just a few examples:

- The Vermont Natural Resources Conservation Service ("NRCS") provides Environmental Quality Incentives Program funds for streambank stabilization only if an interagency "stream team" determines that the project will occur in a stream segment already at or near equilibrium slope such that the erosion will not be just shunted downstream and cause more erosion.[134]
- VTrans recently contracted for the design of modelling tools to combine river and transportation corridor planning (to include the relocation of roads where feasible) and agreed not to fund new local transportation enhancement or bike path projects located in a state delineated river corridor.[135]
- Vermont Agency of Commerce and Community Development provides incentives for river corridor protection through its Community Development Block Grant program and has assembled a large cache of technical assistance through its Vermont Economic Resiliency Initiative web page.[136]
- DEC storm- and waste-water programs minimize the encroachment of outfalls and other treatment structures from contributing to further channelization and disequilibrium within river corridors.[137]

The State is establishing up-front guidance and the "power of the purse" to avoid those encroachments over which it has no regulatory authority but would not have permitted or authorized if it did. Giving municipalities and landowners a consistent message makes a huge difference when trying to change the public expectation that "floods should stay in the channel" and "streams should stay put."

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134. U.S. DEP'T OF AGRIC., ENVIRONMENTAL QUALITY INCENTIVES PROGRAM (EQIP): CONSERVATION PRACTICES (2009), http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_020351.pdf [https://perma.cc/XR8C-HZ4L].

135. *Rivers Program*, *supra* note 29.

136. Chris Cochran, *Vermont Economic Resiliency Initiative*, VT. AGENCY OF COMMERCE & CMTY. DEV., http://accd.vermont.gov/strong_communities/opportunities/planning/resiliency/VERI [https://perma.cc/TBG6-5J9Q] (last visited Apr. 2, 2016).

137. Author's personal knowledge., *supra* note 123.

III. ROLE OF STREAMBANK SOLUTIONS IN LAKE CHAMPLAIN TMDL

A. A Round Peg in a Square Hole

Previous sections defined the impacts of human-caused stream channel evolution at a watershed-scale (i.e., the increased load contribution of streambank and channel erosion) and how Vermont has built a constituency for applying unique landscape-scale solutions. Now the challenge is to explain how the TMDL framework will be used as a tool to get the job done. Inherent in the term "total maximum daily load" is the paradigm of a human-made system that can be controlled. Applying the requirements of a TMDL to programs dealing with nature-based systems, where human "control" is often best avoided, may be an attempt to fit a round peg in a square hole.

1. Difficulty Modeling a Stochastic, Open-System, Precip-Driven Load

Naturally functioning floodplain, wetland, and river systems are valued for the services they provide in remediating human-alterations of hydrology, aquatic habitat, and water quality.[138] These systems have a buffering capacity because of the extensive and open (i.e., uncontrolled) water-sediment exchange with adjoining lands and the natural disturbance regimes that have created them (e.g., floods of various magnitudes).[139] Natural disturbances are not predictable. Their frequencies may only be discerned over long periods of time; they are stochastic. Water, sediment, and nutrient loads going through and out of these natural systems may become altered by humans, but they are not and cannot be regulated in the same way as the material that travels through a wastewater or stormwater treatment system.[140] The storage and transport of organic sediments and phosphorus in stream networks are influenced by topographic vagaries, geologic processes, and the stochastic nature of snowmelt and rainstorms.[141]

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138. U.S. FED. EMERGENCY MGMT. AGENCY, CHAPTER 8: FLOODPLAIN NATURAL RESOURCES AND FUNCTIONS 1, http://www.training.fema.gov/hiedu/docs/fmc/chapter%208%20-%20floodplain%20natural%20resources%20and%20functions.pdf [https://perma.cc/WP23-THHW] (last visited July 1, 2016).

139. Christian Feld, *What Rivers Do for Us*, FRESHWATER BLOG (July 30, 2013), http://freshwaterblog.net/2013/07/30/what-rivers-do-for-us/ [https://perma.cc/QY3N-84K7].

140. *See* FLOODPLAIN NATURAL RESOURCES AND FUNCTIONS, *supra* note 138, at 3–4 (explaining the filtering process of floodplain vegetation).

141. Robert J. Naiman et al., *Fundamental Elements of Ecologically Healthy Watersheds in the Pacific Northwest Coastal Ecoregion*, *in* WATERSHED MANAGEMENT: BALANCING SUSTAINABILITY AND ENVIRONMENTAL CHANGE 127, 138 (Robert J. Naiman ed., 1992), http://andrewsforest.oregonstate.edu/pubs/pdf/pub1608.pdf [https://perma.cc/J2GA-VJ6W].

The urban stormwater and wastewater system has a design capacity, whereas the spatial and temporal scales at which storage and transport occur in "open" river watershed systems are very difficult to predict or model as part of a TMDL. For instance, the sediments entering from an eroding bank in a headwater stream may deposit and erode through successive meander features during small floods, then move down through the stream-river network over several decades before depositing on a broad floodplain near the river's mouth during a larger flood event. The geography and time period of this sequence would be extremely difficult to model.

Collaboration between EPA, Tetra-Tech, Lake Champlain Basin Program, and the Rivers Program used the available hydrology, soil erodibility, and stream geomorphology data to estimate the streambank sediment and phosphorus contributions from the erosion processes (i.e., the movement of material) likely to play out starting at the existing channel evolution stage and, over a period of decades, concluding at an equilibrium stage where storage has been restored.[142] Although still rudimentary, this was a first-in-the-nation effort to include a fluvial geomorphic-based loading calculation in a large watershed TMDL.[143]

There are no dials to turn or units of treatment that can be added. The CWA construct of allocating a daily load and then ramping up the available technology to reduce that particular load is almost antithetical to the program needed to reduce streambank and channel erosion. We cannot structurally control erosion in streams without impairing the stream ecosystem and eventually making the erosion worse.

The Lake Champlain TMDL is remarkable, however, because it takes this round peg and puts it into the square hole. It embraces the idea that our success in reducing streambank and channel erosion will be measured by the removal of structures and the protection of natural floodplain functions, all of which will occur over a much greater time period than would have been believable under the societal pressures that typically exist when a TMDL is required.

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142. *Geomorphic Assessment*, *supra* note 44 (providing access to the Rivers Program's technical assistance for conducting geomorphic assessments); EDDY J. LANGENDOEN ET AL., LAKE CHAMPLAIN BASIN PROGRAM, QUANTIFYING SEDIMENT LOADINGS FROM STREAMBANK EROSION IN SELECTED AGRICULTURAL WATERSHEDS DRAINING TO LAKE CHAMPLAIN 45 (2012); TETRA TECH, INC., LAKE CHAMPLAIN BMP SCENARIO TOOL: REQUIREMENTS AND DESIGN 27 (2015) (explaining the process of channel evolution and impact of human development).

143. Author's Communication with Eric Perkins, Environmental Protection Agency, Region 1.

2. Flood Magnitudes and Frequencies Drive Spatial and Temporal Scales

A course of action that leans on the power of nature to heal begs the question, "How long is this going to take?" The answer lies in how quickly we are able to minimize our obstruction of floodplain redevelopment along incised streams and the length of time it takes for the channel evolution process to play out. The channel widening and floodplain formation stages of the evolution process are driven by floods and are therefore dependent on the magnitude and frequency of flood events.[144] The rate of the process is also a function of sediment supply.

An incised mid-section reach of Lewis Creek (in Addison County, Vermont) evolved and formed a new floodplain after several flood events over a period of five to ten years due to the large quantity of course gravels available in that part of the watershed.[145] By contrast, channel evolution in the incised reaches of the neighboring LaPlatte River may take many decades to play out because of the higher cohesive clay content of the banks and lower quantities of course sediment in the lower part of this watershed.[146] Variability is also introduced by changes in climate. If there are more floods in a wetter climate, floodplains will form faster over larger spatial scales and in a shorter period of time.[147]

B. Functioning Floodplains−Storage at a Landscape Scale

Streambank and channel erosion loads are indirectly reduced when human activities help convert the transport stream into a depositional stream. Instead of focusing on load measurements at the end of a pipe or ditch, the river and floodplain manager should measure available landforms where organic sediments and nutrients may settle and store during the higher frequency storms. At present, only the large, lower frequency floods

144. ZAIMES & EMANUEL, *supra* note 16, at 8.

145. DEP'T OF ENVTL. CONSERVATION, STREAM GEOMORPHIC ASSESSMENT OF LEWIS CREEK PILOT PROJECT REPORT 38 (2004).

146. LAPLATTE WATERSHED PARTNERSHIP, PHASE 2 STREAM GEOMORPHIC ASSESSMENTS LOWER LAPLATTE RIVER & MCCABE'S BROOKE: SHELBURNE AND CHARLOTTE, VERMONT 16 (2007), https://www.uvm.edu/~streams/PDFFiles/laplatte_watershed_partnership.pdf [https://perma.cc/75V8-F2RM].

147. STEPHEN K. HAMILTON, BIOCHEMICAL IMPLICATIONS OF CLIMATE CHANGE FOR TROPICAL RIVERS AND FLOODPLAINS (2009), http://www98.griffith.edu.au/dspace/bitstream/handle/10072/37818/69217_1.pdf?sequence=1 [https://perma.cc/S38R-WPZY].

will stage high enough to access many of Vermont's "abandoned" floodplains.[148]

As floodplains and floodplain forests are restored from headwaters down to the larger river, the watershed's ability to absorb the power of the great floods will also increase.[149] This is significant because not only should sediment transport be decreased year-in and year-out, but Vermont should address the types of dramatic spikes that were seen in 2011 (both from the spring floods and that from Tropical Storm Irene). Hill slope failures are a part of the natural world, but there is little question that the number and magnitude of mass wasting sites (high-eroding embankments) have increased due to the duration of higher flood velocities when great floods occur in a watershed that has been dredged and straightened into a "fire hose" condition.[150]

Based on Vermont's published stream geomorphic assessment data, approximately twenty-five percent of the state's stream miles have functioning floodplains.[151] Considering the nonhuman-caused channel incision, there is a goal of restoring natural floodplain function on up to two-thirds of the moderately to severely incised alluvial stream channels currently found in Vermont.

IV. HOLISTIC SYSTEM FOR PHOSPHORUS STORAGE AND FLOOD RESILIENCE

A. Equilibrium as an Organizing Principle

ANR employs the avoidance strategies that exist at the intersection of Vermont's social, economic, and environmental objectives. To meet the Lake Champlain TMDL requirements, the State and municipalities must implement the same land use protections that would be used to mitigate flood and fluvial erosion hazards. Likewise, to restore complex and self-sustaining river and riparian habitats, rivers are managed toward an equilibrium condition to meander within open corridors where wetland and

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148. *See* Bradley Materick, *Geomorphology: The Shape of a River Corridor*, *in* FRIENDS OF THE WINOOSKI: A PADDLING AND NATURAL HISTORY GUIDE TO ONE OF VERMONT'S GREAT RIVERS 29 (2011), http://winooskiriver.org/images/userfiles/files/Paddling%20Guide%203-31-2011%20low%20res.pdf [https://perma.cc/V2RD-VKWD] (demonstrating that erosion has caused the Winooski River floodplain to lower and that logically only a large flood would be able to reach the "abandoned" floodplain).

149. RIVERWAYS PROGRAM, FACT SHEET #1: FUNCTIONS OF RIPARIAN AREAS FOR FLOOD CONTROL, http://www.lexingtonky.gov/Modules/ShowDocument.aspx?documentid=3470 [https://perma.cc/BW5K-5M4E] (last visited May 11, 2016).

150. KLINE, *supra* note 17.

151. Kline & Cahoon, *supra* note 5, at 4.

floodplains capture and store phosphorus before it causes an algal bloom in the lake.

While this synergy has made it easier to create a greater constituency within the whole of the body politic, meaningful change will be difficult. It has taken more than a decade to get people to understand that we have been trying to solve bank erosion as though we can constrict a river in one place without it expanding in another. DEC was treating symptoms without understanding the disease. There is now a better understanding of the spatial and temporal scales at which erosion happens in a watershed, but we are not dealing with a single landowner or municipality. Achieving the least-erosive equilibrium conditions of a stream will require open valley-bottom land, of which there may be very little remaining in Vermont, depending on one's definition of "open." People who own riparian lands generally do not consider their lands as part of the commons; their lands are an investment for which they expect some form of remuneration.

The science helps make a compelling case that river corridor lands should be held in the public trust (i.e., a part of the commons) as they are essential to the health and welfare of the general public. At the present time, the policy has been to seek buyouts, purchase easements, or promote the municipal adoption of land use bylaws.[152] Many advocate for the State to establish jurisdiction over land use in river corridors, reasoning that to turn theory into practice at the municipal level (i.e., regulating your neighbor) will be very difficult.[153] To help dispel the misgivings about flood hazard zoning, Vermont Law School sponsored an important discussion to clarify that land use regulation for the purpose of protecting public safety has withstood legal challenge from a takings standpoint.[154]

Climate change and water resources may make Vermont an attractive place to live during the remainder of this century, leaving one to guess whether decreases in the number of municipal floodplain and river corridor project reviews would be offset by increases due to the pressures of immigration. With state rules, procedures, and mapping in place, flood damage occurring every year, and the TMDL requirements in place, the interest for broader state authority limiting encroachments in the river corridor is becoming more intensified.

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152. *River Corridor Planning, Protection, and Restoration*, *supra* note 63.

153. David K. Mears & Sarah McKearnan, *Rivers and Resilience: Lessons Learned from Tropical Storm Irene*, 14 VT. J. ENVTL. L. 177, 206–07 (2013).

154. KATHERINE BARNES ET AL., VT. LAW SCHOOL LAND USE CLINIC, MUNICIPAL FLOOD CONTROL REGULATION: LEGAL OPPORTUNITIES AND RISKS 81 (Katherine Garvey et al. eds., 2012), http://ecvermont.org/wp/wp-content/uploads/2013/02/TRORC-floods-final-082712.pdf [https://perma.cc/D37S-LPCZ].

An even thornier question is, "Will the existing open lands be enough to capture the flood flows, sediment, and nutrient that must be attenuated to achieve our public health and safety objectives and if not, how will the state compensate for the lands currently hosting crops or homes that might be needed for floodplain services?" At present, if your tool shed is on the river bank and becomes threatened, ANR is required to authorize bank stabilization unless it can show that the action will endanger someone else. We know that cumulatively each act of channelization makes us less safe and increases phosphorus loading, but definitively showing a singular cause and effect such that the State would condemn a person's investment is a very high bar.

At present, economics and the benefit-cost ratio may be driving the pace of our withdrawal from the river corridor. Channelization is becoming increasingly expensive and government programs are cost-sharing less and less (when we are not in flood recovery mode and politically motivated to make everyone whole). Some infrastructure is starting to move out of the corridor through planning and projects conducted by Green Mountain Power and VTrans.[155] Moving roads would make a very big difference if there could be enough of it; but again, it may come down to the question of, "When does the tool shed or the flood-damaged home need to be removed or should it only happen when the government can afford to buy the person out?"

B. Integration of Instream Process and Stormwater Treatment Systems

Stream geomorphic science tells us that when the flows of a stream are increased, it will equilibrate through erosion to gain a larger sediment load and/or increase resistance with a larger cross-section. Herein lies the important intersection of the stormwater and rivers programs now being expanded to meet the TMDL. The fact that untreated urban stormwater played a significant role in the incision and enlargement of Chittenden County streams is well documented.[156] Now with the role of agricultural

155. VT. AGENCY OF TRANSP., ADAPTING VERMONT'S TRANSPORTATION INFRASTRUCTURE TO THE FUTURE IMPACTS OF CLIMATE CHANGE: VTRANS CLIMATE CHANGE ADAPTATION WHITE PAPER 7–8 (2012), http://vtransplanning.vermont.gov/sites/aot_policy/files/documents/planning/Climate%20Change%20Adaptation%20White%20Paper.pdf [https://perma.cc/9WZZ-ASUG]; INST. FOR SUSTAINABLE CMTYS., VERMONT'S ROADMAP TO RESILIENCE: PREPARING FOR NATURAL DISASTER AND THE EFFECTS OF CLIMATE CHANGE IN THE GREEN MOUNTAIN STATE (2014), http://www.iscvt.org/wp-content/uploads/2014/06/vermonts-roadmap-to-resilience-web.pdf [https://perma.cc/FQ54-VHFV].

156. *See* VT. AGENCY OF NAT. RES., WINOOSKI RIVER BASIN WATER QUALITY MANAGEMENT PLAN 5, 43 (2012),

and municipal road-related stormwater being factored into the Lake Champlain TMDL, there is an increasing challenge to understand the nexus between the ditch and the stream.

New rules will attempt to define best practices that would reduce the hydrologic and instream modifications that often follow farmland and roadside drainage. In small watersheds, DEC and its partners will spend many days in the field deciphering where ditches end and perennial streams begin. Due to its investments in understanding river science, Vermont is uniquely poised to design an efficient process for delineating these intersections and learning to combine the traditional stormwater practices with stream equilibrium principles and practices.

One challenge is making the outlet of a stormwater conveyance blend into the natural floodplain as it enters the river corridor. If the ditch outfall, spreader, or settling area is hardened and becomes an immutable structure that must be protected from stream meander migration, then the stormwater treatment system becomes part of the overall channelization problem causing streambank and channel erosion. At present, ANR is working to ensure that state technical, regulatory, and funding assistance for stormwater treatment is predicated on system designs that do not further impede channel evolution or equilibrium processes within the river corridor.[157]

C. Lake Champlain TMDL Is a Milestone in U.S. Watershed Restoration

This article ends with a question: "Will Vermont's efforts to implement the Lake Champlain TMDL help create a populous that is striving to live and work outside the natural floodplain, entering the corridor only when we must, as a guest of the river?"

One could argue that never before has a state, with its local, regional, and federal partners, created the set of ingredients that might now be combined to bring about this cultural change. A TMDL written and adopted by EPA that recognizes the space and time needed to not only accommodate new structural pollution treatment systems but the nature-driven processes that will create functioning, landscape-level treatment systems, is truly a milestone in U.S. watershed restoration.

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http://dec.vermont.gov/sites/dec/files/wsm/mapp/docs/mp_basin8final.pdf [https://perma.cc/7FJH-SMN9] ("The basin occupies . . . a little less than half of Chittenden County.").

157. *Stormwater Program*, VT. DEP'T OF ENVTL. CONSERVATION, http://dec.vermont.gov/watershed/stormwater [https://perma.cc/E6ZD-A27H] (last visited May 11, 2016).