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A FRAMEWORK FOR ACTION ON STORMWATER:
Ridge to River Phase 1 Final Report

May 16, 2016

Introduction

In larger cities and towns, including many of Vermont's more urbanized communities, the landscape of stormwater management has evolved into a well-defined area of municipal programming that encompasses—to varying degrees—issues related to both water quality and flood resilience. Rural towns and villages in Vermont and elsewhere have struggled with what to do about the impacts of stormwater as the typical urban strategies, regulations, and practices simply do not translate. In places where road systems are extensive and development diffuse, where forestry and working lands are as much a part of the landscape as homes and village centers, identifying critical runoff and pollutant sources and the best management strategies is a far more elusive process.

The High Meadows Fund at the Vermont Community Foundation awarded funding to the Friends of the Mad River (FMR), on behalf of the Mad River Valley's (MRV) watershed stakeholders, to work together across the five towns in the watershed to improve flood resilience by tackling the challenges associated with stormwater runoff. This was one of six grants awarded throughout Vermont to groups working across municipal boundaries to find creative solutions that protect communities, land, and water. The grant is intended to lay the foundation for a long-term effort to proactively manage stormwater throughout the MRV.

This report is intended to guide development of an "Action Framework" for the MRV's watershed stakeholders: its five municipalities of Duxbury, Moretown, Fayston, Waitsfield and Warren; the Friends of the Mad River, Mad River Valley Planning District; and its ski areas, businesses, associations and residents.

Ultimately, the Action Framework will identify the suite of regulations, programs and projects needed to support MRV communities as they understand, adjust to, and rise to the challenge of meeting not only changing state regulations, but also broad and evolving watershed goals related to water quality and resiliency. These include:

- **Making the Connection**: Education on the link between the routine decisions and actions of the Valley's elected and appointed officials, road crews, contractors, foresters, farmers and land owners, and stormwater runoff in the Valley.
- **Limiting, Identifying and Correcting Erosion and Stormwater Runoff from Land Disturbance**: Implementing regulations, procedures, trainings, policies, inspection and reporting protocols, and opportunities for the public to participate in reducing the impact of erosion and stormwater runoff from land disturbance of all types in the Valley.
- **Enhancing Practices For Roadways**: Supporting continued evaluation and enhancement of the planning approaches, information management, maintenance and repair techniques, and capital

projects used by the Valley's road crews and contractors, in order to increase the resilience and reduce the adverse impact of roads on stormwater runoff.

- **Lightening the 'Water Footprint' of Valley Land Uses**: Providing incentives, education, technical expertise and financial support to remedy problems associated with existing development, driveways, and recreation trails, and prevent new ones from occurring.
- **Keeping New Activities 'Blue and Green'**: Ensuring that municipal land development permitting process, development standards, and enforcement procedures require effective erosion control and stormwater management practices.
- **Partnering With Working Lands Stewards**: Working with farmers and foresters, and Vermont agencies implementing new and evolving regulations, to promote partnership projects that enhance the Valley's water quality.

Over the past five months, the consulting team of Stone Environmental and Birchline Planning LLC have completed a series of information gathering tasks that are presented in this report. These include:

- Reviews of existing plans, policies, programs and other available information related to the condition and management of the Valley's watersheds and surface waters;
- Interviews to gather information and insights from municipal staff, elected/appointed officials, and other stakeholders; and,
- GIS-based assessments of physical watershed characteristics.

The goal was to compile, consider, and ultimately integrate existing environmental data about the current condition of the MRV landscape with an evaluation of the current, state and local programmatic framework (e.g., development review, enforcement, planning, road management and maintenance, budgeting) that both directly and indirectly addresses stormwater management and landscape resiliency. This integrated assessment, as summarized here, provides a foundational assessment of needs and strengths – upon which the Action Framework can be built.

What is a "Stormwater Program" for a Rural Region?

What is a "stormwater program"? The answer is complex and involves municipal plans, regulations and authorities, transportation system management, existing and prospective land development, and the management of working lands. The answer also will, necessarily, evolve continuously in response to changing regulations, economic conditions, municipal capacity, and priorities. Further, major events, such as Tropical Storm Irene in 2011, and the spring storms that affected the Mad River Valley in 2014, can upend a carefully-prioritized stormwater program without warning.

This report is intended to help the Taskforce begin to frame the core activities – policies, programs, and projects – and content of a stormwater program for the five-town portion of the Mad River Valley watershed, to identify how effectively current activities address stormwater pollution and resiliency concerns in the watershed, and to offer options and considerations (a menu of options) for implementing a stormwater management plan and other actions to enhance resiliency in the future. As a compliment to the detailed natural resource assessment in Section 3, the qualitative research process focused on (1) what the Valley is doing, as a whole, about stormwater management policies, programs and regulations; (2) what key elements the Valley is not carrying out relative to stormwater management that could enhance watershed health and resilience if implemented; and (3) what successful policies and activities from other communities could, potentially, be implemented in the Valley to close gaps or enhance the effectiveness of current programs.

Organization of this Report

This report is organized in four sections. Section 1 summarizes and synthesizes the key findings from the programmatic review (provided in Section 3) and environmental data assessment (presented in Section 4). Section 1 is intended to provide a concise basis for reviewing, prioritizing, and taking action on specific implementation steps. Section 2 consists of an Implementation Matrix, which offers the Task Force a robust suite of possible projects, programs and regulatory actions which could be incorporated into the Action Framework. In the matrix, each implementation option is related to the stormwater-related problem or resilience challenge the option would address. Sections 3 and 4 include details of the policy and programmatic evaluation, and the environmental data assessment, respectively.

Because implementation of a stormwater management plan is dependent upon so many individual, discrete actions and authorities beyond the scope of any one report, or task force, the findings from this report must not be taken as a specific or exhaustive list of recommended actions. Instead, this report should be used as a platform for different stakeholders to apply in considering, modifying, and ultimately selecting options that can enhance or compliment current efforts, respond to regulatory changes and unforeseen events, and help the community respond to the ever-evolving opportunities and needs of watershed management.

1. THE COMPONENTS OF A STORMWATER PROGRAM

To organize the assessment of what the Valley is doing, what key elements are lacking or could be enhanced, and what options could be transferred from other communities, this portion of the report is organized around the basic components of a municipal stormwater management program as defined by US EPA, plus topic areas with issues unique to the Valley and the stated desire to expand the focus of this effort to include resilience concerns: Transportation, Working Lands, and Addressing Existing Development.

Since the 1990s, the US EPA's Phase II National Pollutant Discharge Elimination System (NPDES) program has set out "minimum measures" required of all permitted municipal stormwater programs. While the Valley towns are not subject to the EPA's Phase II program, many of these measures are useful benchmarks for any stormwater management program, and include: public education and outreach; public involvement and participation; construction site stormwater runoff control; and post construction stormwater management.

The measures provide a means for structuring recommendations that addresses the most substantial areas of programmatic need in the Mad River Valley, and serve as a framework for conducting a similar evaluation in other communities or watersheds. Because the measures are drawn from national work by EPA, there are additional topics important to the MRV's rural landscape that need to be considered in comprehensively considering the components of a stormwater program for the Valley. Most importantly, management measures related to roads and working lands are not discussed separately in EPA's framework, and so we include discussion of these measures following information about EPA's measures.

For each measure, examples are provided of what would constitute a "basic" program, and then a more aggressive or enhanced program, drawing on examples from Vermont and across the U.S. as appropriate. The current status of each program component in the Valley is cited. An Assessment and Recommendations section then follows the discussion of each measure, identifying important program elements that are missing or could be enhanced.

1.1 Public Education and Outreach

Public education and outreach efforts play a critical role in ensuring the public has robust information on the problems caused by stormwater pollution and the benefits of stormwater management including, ultimately, enhanced landscape resilience. Common elements of a public education and outreach program on water quality issues are presented in the table below.

Typical Program Components:	Basic Program:	Enhanced Program Examples:	Valley Current Status & Program Considerations:
Website	Town of Rutland http://waterwise-rutlandtownvt.com	South Burlington Stormwater Services (www.sbstormwater.com) Interactive map, projects, enforcement cases	Scattered pieces on websites of Friends of the Mad River, MRVPD, sugarbush.com/discover/environment/, Mad River Glen Naturalist Program
Printed Materials	Basic stormwater fact sheets or bookmarks (see www3.epa.gov/npdes/pubs/after_the_storm.pdf)	High-quality, visible plan similar to *The Best River Ever* OR specific, targeted outreach	No visible, printed materials on preventing stormwater runoff; possible targets could include foundation drains and yard management, small contracting projects
Public Presentations	Presentation during scheduled public meeting on capital budget, regulatory changes, plan update	Consistent presentation or education series through towns, Rotary, Chamber; in-school curriculum	FMR, MRVPD work but not specifically stormwater-focused; Select Board, Planning Commission, DRB members report relatively little specific education/ discussion on how stormwater management relates to municipal decision-making and development review
Media Engagement	Basic press release on program; example: vtdigger.org/2014/03/18/town-rutland-launches-stormwater-pollution-campaign/	"Storm TV" video series running on local cable, websites; Town of Chapel Hill, NC high-quality video on pollution prevention. See examples on WEF's "StormTV" YouTube Channel, www.youtube.com/playlist?list=PL4C55204EF5052D5B	Valley Reporter, MRV TV – no formal watershed/ stormwater presence but strong knowledge of flooding, stormwater issues from Irene[1]

Assessment and Recommendations: There are 'pieces and parts' of public education on stormwater management and landscape resilience in the MRV in many different places, and from many different sources. To date, however, there has not been a concerted effort to link these different environmental education pieces into a specific, Valley-wide 'push' for stormwater education. **With respect to websites,** pieces of education on watershed restoration, erosion control, pollution prevention and green infrastructure are found on the

[1] TCR L. Loomis, 2/24/16

websites for each Town, FMR, MRVPD, Sugarbush and Mad River Glen websites, and sustainability practices (though not stormwater specifically) are features on the websites of many of the Valley's businesses[2]. However, notably, not even the FMR website has a specific "stormwater" heading.

The efficacy of **printed materials such as brochures** and manuals is a topic of great contention in non-point education circles[3], while videos and cable TV content have been promoted recently as more effective by US EPA and the Water Environment Federation. High-visibility, high-quality reports driven by a strong public education push – not unlike *The Best River Ever* published by Friends of the Mad River in 1997 – are consistently found to be the most successful in promoting behavior change. At present, there are no evident printed materials on stormwater management specific to the Valley. Options for printed material include:

- Preparing a high-quality, Valley-wide stormwater plan; or,
- Developing issue- and audience-specific printed materials, such as earth moving activities on residential sites or identifying and reporting erosion control issues.

In many cases, water quality problems result from land owners or contractors using equipment to replace culverts, re-grade driveway aprons, change residential grading, or add foundation drains. ***Education and outreach targeted to contractors and equipment operators is an "opportunity zone" for improving water quality***. Any investment in printed materials should, however, be evaluated in light of the need to make a significant investment in order to have a substantive impact.

Preparation of a video for **media engagement** on stormwater management, focusing on a Valley-specific issue such as earth moving activities on residential sites or identifying and managing erosion, is worth considering. MRV TV provides an excellent outlet, and the recent development of WEF's Storm TV YouTube Channel (https://www.youtube.com/playlist?list=PL4C55204EF5052D5B) provides a wealth of peer-reviewed examples of targeted and effective public education videos.

The Task Force is urged to consider developing a basic "Stormwater 101" **public education** presentation with the findings of this study, oriented to the education needs of the elected and appointed boards in the Valley Towns. In all of the interviews with Select Board members, Planning Commission members and DRB members, the question was asked "How often, and in what context, is stormwater management discussed?" The answers were, quite consistently, something to the effect of "Not much," "not very often," and "only as it relates to roads and highway department costs." Providing an educational presentation with clear links

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[2] Examples of Valley business that feature environmental practices (though not stormwater management) on websites include but absolutely are not limited to Small Dog Electronics, Maclay Architects, and Tucker Hill Inn.

[3] See for example Taylor, Andre, Rob Currow, Tim Fletcher, and Justin Lewis, "Education campaigns to reduce stormwater pollution in commercial areas: Do they work?" Journal of Environmental Management, Vol. 84, Issue 3, 8/2007.

between municipal investment, policies or development standards and the resulting impact or benefit for stormwater is an important gap in stormwater program development that should be addressed.

In particular, the impact on municipal budgets of adopting VTrans road standards, which will be required by the Municipal Roads Permit, but is still an 'unknown' to many, is an important topic for public education. While the Town road crews and many Select Board members report a strong knowledge of the practices required in the VTrans Municipal Road and Bridge Standards, Planning Commission members in some Towns do not have a working knowledge of why certain practices, such as stone lining, are now being required. ***Providing education and an overview of the VTrans standards and best practices for all Valley Planning Commissions*** will help with policy development and overall support for improved maintenance.

It is also very important to help citizens/taxpayers understand the cost basis for road maintenance in general, for water-quality related costs of capital projects such as bridge and culvert repairs, and especially for upgraded approaches to maintenance such as stone lining of ditches. This was stressed in all five Towns, and by Town staff, elected officials, appointed officials and other stakeholders. Education around the "why" and "how much" with accurate cost data and comparisons could do a great deal to build greater community support for water quality-related projects.

1.2 Public Involvement and Participation

Public involvement and participation measures are centered on providing opportunities for the public to shape policy and regulation, and to participate in preventing stormwater pollution, enhancing water quality, and improving watershed resilience. Common elements of public involvement and participation programs are presented in the table below.

Typical Program Components:	Basic Program:	Enhanced Program Examples:	Valley Current Status & Program Considerations:
Surveys	Simple, Town Meeting survey on awareness	City of Burlington Integrated Water Quality Plan Survey (2015) on community benefits of different investments (See discussion on Sustain Champlain Blog, sustain.champlain.edu)	Surveys have been successful in past (MRV Economic Study is good recent example); none recently on water quality or stormwater *per se*
Citizen Reporting	Phone number and email on website for reporting illicit discharges, excessive erosion	Prairie Rivers Network, Citizen Stormwater Patrol training for construction site erosion control monitoring (Example: Prairie Rivers training citizens in erosion control monitoring prairierivers.org/articles/2009/03/citize	Parallel efforts (Keeping Track, concerned citizen calls to FMR) but no active program; municipal zoning administrators and road crews, supervisors are responsible for finding and dealing with violations

Typical Program Components:	Basic Program:	Enhanced Program Examples:	Valley Current Status & Program Considerations:
		n-stormwater-patrol-training-a-success)	
Follow-Up from Citizen Reporting	Procedures for ZA or public works to inspect sites adopted in municipal ordinance	Photo examples of erosion problems on website (Example: Charlotte-Mecklenburg Storm Water Services, charmeck.org/stormwater/ReportPollution/pages/reporterosionproblems.aspx) Trained personnel (on-call contracted or Town staff with training) available to follow-up on reports, work with landowners and recommend corrective action	Minimal system in place; no "Who to call if you see…" or examples of types of erosion on websites for erosion (or any other zoning violations); many officials report "We hardly ever deal with violations," ZA level of knowledge/ ability varies among towns.
Clean-Up, Stream Team Days	One event/ year, municipal or in partnership with non-profit	Active citizen teams involved in restoration, inspection & property owner contacts	Outstanding public involvement with FMR on monitoring, stream assessment, restoration over decades; not focused on stormwater *per se*

Assessment and Recommendations: Public involvement and participation is an area where the Valley has shone with respect to its water resources. Engagement in river monitoring, assessment, and restoration, along with habitat conservation, trail construction and management, and other forms of stewardship has become a hallmark of the community. The Valley also has used surveys successfully to engage the public and assess many different types of information; the recent Economic Study is a good example of a successful process. Again, these efforts have not been focused on stormwater *per se*, but the framework for this type of engagement is certainly in place.

In the context of a stormwater management plan for the Mad River Valley, a significant opportunity for expanded public involvement and participation would be developing a framework that enables, encourages and empowers residents to **report active erosion sites** leading to discharges into stormwater conveyances or surface waters. In the background interviews conducted for this project, zoning administrators, DRB members, forestry stakeholders, elected officials and road crews all stated that poorly managed land disturbance can be observed to cause impacts in the watershed – but in a rural area with a distributed road network, much of the actual land-disturbing activity goes unreported or is not discovered until the damage is done.

Increasing citizen engagement in finding and reporting erosion issues is an important opportunity to build a more effective stormwater program in the Valley. Communities elsewhere in the US provide many examples of successful and effective public involvement frameworks for educating citizens on erosion problems, and engaging them in reporting - and even in the inspection or monitoring process. Ideally, each Town website and the FMR website would have clear photos of the types of erosion issues that should be reported, contact information, and instructions for how to report observed erosion problems[4]. The next program area for development is to **provide support for effective follow-up**. Zoning administrators all report that supplemental training, and/or having contracted on-call support available to inspect and recommend corrective actions where erosion problems are observed and reported, is essential to enable them to respond more effectively to water quality issues.

1.3 Construction Site Stormwater Runoff Control

The local regulations in place in the Valley towns (zoning, subdivision, curb cut review, and culvert/roadway standards) provide some basis for oversight over construction erosion for subdivisions, driveways, and new construction. Prohibitions or strict limitations on construction on steep slopes have been effective overall, and are in place in all but one town. Revisions underway in Moretown and Duxbury offer an opportunity to greatly improve construction-phase (and post-construction) stormwater runoff control provisions. In addition, all of the DRB members interviewed as part of the project report that the quality of subdivision plans, and the level of oversight of curb cuts and culverts by road crews, has improved. Fayston and Warren have by far the most comprehensive provisions related to construction site controls - with the caveat that enforcement, technical support for plan review and inspection, and effective permit conditions must be in place as well, or even a detailed and well intentioned bylaw will be ineffective.

However, ***the "universe" of land-disturbing activities addressed by municipal zoning and subdivision reviews is only part of the water quality picture*** in the Valley. Small sites, minor land-disturbing activities (i.e. driveway repairs and culvert replacements, residential site re-grading or drainage changes), and forestry – or "quasi-forestry" – activities that are not subject to zoning and subdivision regulations are known to be contributing to water quality problems. Outreach to property owners and contractors on erosion control provisions and permit conditions has been stepped up in some towns, and with successful results in many cases. However, the relatively small number of activities that are permitted, and inconsistent knowledge among ZAs on some aspects of erosion control, are limitations on the effectiveness of enforcement.

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[4] Charlotte-Mecklenburg Storm Water Services website cited in the table provides one of the better examples and comparables for Task Force consideration.

Erosion Control Provisions Adopted in Valley Municipal Bylaws; provisions marked with a "+" provide (in the consultant team's professional experience and judgment) a relatively higher degree of specificity, clarify, or certainty around erosion prevention and stormwater management issues than provisions marked with a "-". See discussion of "specificity and content" in tables that follow.

Duxbury	Moretown	Waitsfield	Warren	Fayston
- Gravel and soil extraction requires erosion control in operations plans - Erosion control is a "special consideration" for DRB reviews	- Conditional use and PUD require "erosion control, storm water management or site reclamation plans" only where required by the DRB - Very basic standard for Conditional Use approval - Minor earth extraction, quarrying and mining requires "acceptable erosion control and site restoration plan"	+ Roads, driveways, utility crossings, recreation paths through stream buffer must comply with VT Handbook (reference outdated) - DRB may impose conditions "as it deems relevant" for "temporary and permanent erosion control, including project phasing to limit exposed area" - Conditional use permits must include an erosion control plan, but plan does not include control measures - Site plan requires stormwater management and/or erosion control plan "as appropriate"	+ Sec. 3.4 erosion control & development on steep slopes requires erosion control plan using VT handbook + Sec. 3.4 specifically allows independent technical review of plans - 7.5 Stormwater Management & Erosion Control; allows DRB to require on all subdivisions; some conflict when projects also require a State permit.	+ Erosion control must be implemented for all development requiring a municipal land use permit and forestry. + Erosion control plan required for driveways with steep grades + Section 3.4 Erosion and Sediment Control and Stormwater Management; + Only projects requiring a state permit are exempt (recommended) - Erosion control and reclamation plan must be submitted for sand and gravel operations

The table below outlines the typical components of a compliant and enhanced program, and notes how these provisions relate to the status of regulations in the Valley towns.

Typical Erosion Control Program Components:	Basic Program:	Enhanced Program Examples:	Valley Current Status & Program Considerations:
APPLICABILITY	Municipal ordinance requires erosion control plans, measures for projects disturbing > 1 acre, and not requiring a state permit	Municipal ordinance requires erosion control measures for all land disturbance > 400 SF, Burlington, VT small	Ranges from minimal requirement (Duxbury) to requiring erosion control for all activity subject to a municipal permit (Fayston)

		projects erosion control permit[5]	
EXEMPTIONS	Land disturbance < 1 acre (40,000 SF) Often exempts		Fayston: exempts activity not subject to a zoning permit
FORESTRY	MS4 program generally exempts forestry	Municipality may include clearing as "land disturbing activity" subject to erosion control requirements	Fayston: requires plans for "forestry"; all towns, question what qualifies as "forestry" vs. site clearing
MUNICIPAL ACTIVITIES	Municipal activity exceeding thresholds for land disturbance must use equivalent erosion control	All municipal land-disturbing activities must use basic erosion control procedures (Proposed for City & Town of St. Albans)	No provisions adopted; road crews observe different policies on closing sites, activity before rainstorms
'GOOD HOUSEKEEPING'	Basic measures including covered storage of salt and sand piles	Use of hydroseeders/ vactors for operations, BMPs for erosion control observed for all municipal operations	All Valley towns have adopted VTrans standards; Warren, additional measures in place **Municipal Roads Permit (Act 64) creates substantial new requirements

Assessment and Recommendations: The qualitative and quantitative assessments performed for this study indicate that improving the regulatory basis for implementing and enforcing erosion control and applicable municipal "good housekeeping" requirements in the Valley is one of the most obvious and potentially beneficial areas for stormwater management. While the State of Vermont requires construction-phase erosion controls for projects that disturb one acre or more of land area, either on an individual site or as part of a common plan of development, the only development in the Valley requiring State-level review in recent years was the redevelopment of Sugarbush Resort's base area. Thus, the municipalities are the level of government (rather than the State) with the ability to require erosion control measures for the vast majority of land disturbing activities in the Valley.

Enhancing local regulation of construction-phase disturbance involves two different areas of municipal authority and operations, both of which are challenging: (1) Changes to provisions in municipal bylaws, development review procedures and enforcement; and (2) enhancement of the erosion control measures used by municipal road crews. Both require action and investment by Planning Commissions and Select Boards in

[5] https://www.burlingtonvt.gov/sites/default/files/DPW/Stormwater/Small%20Prj%20EPSC%20form%202012-9-4(v4).pdf

each municipality, and substantial buy-in and time commitments from municipal staff. ***If and when erosion control provisions are written by DRBs, or added to zoning or land disturbance permits, Zoning Administrators need support and training to provide effective compliance assistance and enforcement.***

Bylaw amendments are not as simple as "adding language" to a municipal code. There are several factors, each of which requires consideration in each municipality. These are complex discussions that will require technical expertise, political consideration, and buy-in from staff and the regulated community. In several cases listed in the table below, implementing a plan recommendation would require an investment by the associated Town in training, staff or consultant time, and legal counsel to enhance the quality of review and the effectiveness of development conditions, which are an important – but according to the Valley's zoning administrators and DRB members – often ineffective means of managing construction impacts from development. Moreover, bylaw amendments around erosion control are often easiest completed in the context of larger 'overhauls' of zoning regulations, which are now underway in two of the Valley Towns. Moretown is working on bylaw revisions and using Fayston's as a model, and Duxbury will begin its zoning update process in April, 2016. Conversations around potential changes in Waitsfield (standards and administration), Warren (administration) and Fayston (administration) would thus need to take a different approach.

The table below breaks down the specific issues with municipal bylaws and erosion control into specific factors and issues for the Valley[6]. This table is intended to provide the Task Force with an overview of the types of issues that each community will need to review as part of its own deliberations about erosion control, and to inform education and advocacy efforts with the individual towns.

Factor	Description	Specific Issues for the Valley
APPLICABILITY & EXEMPTIONS	What land-disturbing activities are required to submit erosion control plans? Typical programs, any subdivision involving utilities or other construction, any driveway culvert, site plan or PUD, conditional uses involving construction; more advanced programs, all activity except statutory exemptions	Single- and two-family homes, driveways/culverts, & forestry all exempt except in Fayston. Waitsfield, Moretown make erosion control plans optional for subdivision, site plan, conditional use Require a permit with erosion control standards for all driveways/culvert replacements? (see Bayside, WI permit example)[7] Can activities that are not commercial forestry be regulated?

[6] Because of the challenges around enforcement, and landowner considerations, specific cases and development projects that were discussed or cited by zoning administrators in the research process are not specifically identified.
[7] http://www.bayside-wi.gov/DocumentCenter/View/548

Factor	Description	Specific Issues for the Valley
THRESHOLDS	How much land disturbance must occur to be subject to the requirements; typical thresholds are 5,000 SF 20,000 SF or 1 acre	What is political appetite for requiring all land disturbance >400 SF to get a permit? What about reduced/"light" standards for all smaller projects?
SPECIFICITY & CONTENT	Plans must require basic information (off-site flows, proximity of surface waters, limits of disturbance, BMP locations, etc.) to be effective; see sample ordinance from Burlington, VT and MMSD Green Infrastructure Codes	Fayston, Warren require specific information. Waitsfield missing key information from plan requirements. Warren requirements may conflict with VT erosion control permit requirements for large projects; consider allowing state submittal to be sufficient for large projects.
TECHNICAL REVIEW	Enabling technical review by outside consultant / contractor with expertise at applicant's expense (for DRB permits), town budgets or fees	Only Warren ordinance specifically authorizes technical review of erosion control plans; consider adding provision in other towns' bylaws when amended
APPROVAL CONDITIONS	Approval conditions related to erosion control must be technically sound and readily enforceable	Valley ZAs, DRBs report this is a substantial issue. Training and the availability of outside help, including legal counsel, is needed.
INSPECTION	Basic erosion control permits require inspection (municipal or contracted) at commencement, before permanent SW controls are implemented, at close-up, and after 1/2" rain events.	Minimal inspection is conducted. Staff do not have sufficient time or training. Contracted staff, volunteers or requirement for self-certification are options. How many inspections? Should bonds/sureties be held in some cases? (requires bylaw amendment except Fayston)

Erosion control and other similar 'good housekeeping' activities around municipal operations in the Valley are straightforward from a technical perspective, and relate to three factors: (1) Consistency in using erosion control BMPs for all land disturbing activities; (2) quality of practice, such as ensuring that crew work schedules include sufficient time to close up and cover sites before the end of a work day, rescheduling land disturbing activities when rain is forecast, and ensuring that all crew members are proficient in a standard set of BMPs and practices; and (3) equipment and materials, notably access to a hydroseeder, sweeper or vactor. These issues are discussed further in Section 1.5.1, below.

1.4 Post-Construction Stormwater Runoff Control

Because of the intrinsic link between stormwater runoff and land development, which involves the creation of impervious surface and roads, most municipal stormwater programs focus strongly on imposing requirements for permanent, post-construction stormwater controls on new and re-developed impervious surfaces. In more rural Vermont communities, municipalities often rely on Vermont DEC's statewide permitting program to ensure that controls are imposed on projects of any substantial size. Within the Mad River Valley, the analysis in this study has shown what many already knew: Outside of the Sugarbush base area reconstruction projects, the scale of development projects in the Valley in the past decade has not been large enough – creating one acre of impervious surface or more – to trigger state operational permitting. Incremental land development, particularly construction of single-family residences on individually permitted lots, has proceeded without requirements for stormwater management following construction.

This situation may change somewhat in the future if a proposal to reduce the threshold for a State operational stormwater permit is reduced from the current 1 acre of new impervious surface to a more aggressive standard of half an acre of new impervious cover. From discussions with zoning administrators, planning commissioners and DRB members, it is likely that a standard at this threshold may bring some planned residential subdivisions under State jurisdiction. However, other than ski area development and perhaps a limited amount of commercial development in Waitsfield and Moretown, it is still more likely than not that municipal regulations will represent the much more important opportunity for imposing some requirements for post-construction control when land use change occurs.

As with the erosion control requirements described above, provisions in zoning and subdivision regulations related to post-construction stormwater runoff management run the gamut from minimal or negligible requirements, to Fayston's well-developed stormwater management provisions that include standards for the use of green infrastructure. It is important to note that while most urbanized areas deal with stormwater management standards in terms of managing a particular volume of runoff, and/or meeting standards for pollutant removal, none of the MRV's local bylaws specify a particular volume to be managed, design storm, or pollutant reduction target.

Post-Construction Stormwater Control Provisions Adopted in Valley Municipal Bylaws

Duxbury	Moretown	Waitsfield	Warren	Fayston
- 7.2 Approval of sand and gravel extractions requires "provisions to prevent discharges to nearby surface waters or drainage systems."	- 4.11(B) requires stream buffer; - 5.11 allows Planning Commission to request information on stormwater management; 5.2 Conditional use standard includes minimizing runoff from parking lots and developed areas; Mining, extraction requires	- Zoning Section 3.12 requires stream buffer; - Zoning Section 5.03 Conditional Use review includes "consideration" of adequacy of stormwater management and includes condition (D)(5) which allows but does not require the DRB	+ 3.13 Surface water protection requires stream buffers + 7.5 Stormwater Management & Erosion Control; allows DRB to require on all subdivisions	+ Section 3.4 Erosion and Sediment Control and Stormwater Management; + Only projects requiring a state permit are exempt (recommended)

Duxbury	Moretown	Waitsfield	Warren	Fayston
	demonstration of stormwater management	to request a stormwater management plan; + Subdivision Section 3.4 Storm Water Management & Erosion Control requires "stormwater management systems…" to be designed by an engineer with management responsibility assigned; State permit may be substituted		

Typical Program Components:	Basic Program:	Enhanced Program Examples:	Valley Current Status & Program Considerations:
APPLICABILITY	Municipal ordinance requires stormwater management plan for specific projects	All site plans, subdivisions; anything > zoning permit and anything creating > 500 SF of impervious surface (see Bayside, WI; impervious surface permit required for >50 SF new)	Stormwater management plans ONLY required in Warren and Fayston, some Waitsfield subdivisions, or where required by State; primarily discretionary in Moretown, Waitsfield
THRESHOLD/ EXEMPTIONS	Redevelopment, single-family development exempted; projects subject to state permitting do not require local review	Projects modifying less than 5,000 SF of impervious cover do not require full stormwater management plans; small-scale BMPs required for most development; few exemptions other than statutory (i.e. federal facilities). Note: Enhanced programs often defer to state for projects triggering state review to avoid conflict, duplication	Most development exempted
REQUIRED MEASURES	Control of volume, peak discharge for 2- and 10-year storms; TSS removal per published design standards for different BMPs	Infiltration of one-year storm (2.4"/24 hours) OR maximize treatment (flow-through) or where possible infiltration of first 0.5" of rainfall.	**Valley bylaws do not include numerical standards + Fayston (3.4) has qualitative standards for incorporation of LID (green infrastructure) measures into site design and post-construction measures

Assessment and Recommendations: The status of post-construction stormwater requirements in the Valley is very similar to the status of erosion control requirements. For the most part, sites are not subject to any requirement for creating permanent, post-construction stormwater controls for driveways, houses, or any other types of permanent impervious surface. As with erosion control, many small sites, minor land-disturbing activities (i.e. driveway repairs and culvert replacements, residential site re-grading or drainage changes), and forestry – or "quasi-forestry" – activities that were not subject stormwater management regulations, or in some cases even zoning permits, have been identified by zoning administrators and others interviewed in the stakeholder process as contributing to water quality problems.

Through the environmental assessment and the background interviews, a suggestion has been raised that the Valley consider some requirement for minimal stormwater management controls for projects ranging from single- or two-family structures to larger projects that are "just short" of State permitting thresholds. The experience of communities that implement some management requirements on even very small projects – the lakeside Village of Bayside, Wisconsin requires a brief review and minimal control measures for projects adding 50 SF of impervious surface or more – provides good evidence that some control measures can be implemented without adverse effects on project cost, equity, or development feasibility. Vermont's *Small Sites Guide for Stormwater Management*[8] provides a guide to low-cost, minimally disruptive approaches to maximizing sheet flow and infiltration, and minimizing the conveyance of concentrated runoff post-construction requirements for single-family residential or smaller projects. Municipal zoning provisions (or, at a minimum, guidance with zoning permits) requiring these practices be incorporated into single-family homes and larger projects would provide a baseline for post-construction management that could provide benefits Valley-wide.

The findings related to post-construction stormwater control also highlight the fact that **ski area development and redevelopment projects represent tremendous opportunities** to improve post-construction stormwater management – and in the case of recent improvements at Sugarbush Resort, illustrate the importance of supporting and facilitating larger redevelopment projects that provide opportunities for water quality-improving investments. The recent enactment of retrofit requirements for impervious surface areas of 3 acres or more in Vermont Act 64 is likely to require some development in the base area at Lincoln Peak to complete retrofit projects, which presents another opportunity for larger-scale development to become a catalyst for improvements. For those land development areas that are not large enough to trigger either development permitting or the retrofit requirement, such as some of the Valley's larger gravel parking lots,

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[8] dec.vermont.gov/sites/dec/files/wsm/stormwater/docs/Permitinformation/ResidualDesignationAuthority/sw_rda_small_sites_guide.pdf

the Task Force could consider targeting these areas for partnership projects to implement high-visibility post-construction stormwater BMPs.

1.5 Additional Valley-Specific Program Elements: Transportation, Addressing Existing Development, and Working Lands

1.5.1 Transportation

The Town Plans in the Valley describe and support actions that address stormwater management and erosion control from land development, but do not directly address stormwater management and the transportation system. ***All five Valley towns have adopted the Vermont Agency of Transportation Road and Bridge Standards.*** There are differences of opinion on the appropriateness of some of the standards and practices – particularly the use of plastic culverts and some aspects of ditch shaping and maintenance. Further, ***there is tremendous concern about the potential impacts on Town staff of the impending Municipal Roads General Permit***, which will begin to be implemented in 2018. ***As Town Plan policies are updated, the water quality/transportation nexus should receive greater attention.***

Some "common-sense" road maintenance practices, such as scheduling project work to ensure construction sites are closed up before the end of the workday and not opening sites when substantial rain is forecast, are generally – but not always – observed by Town crews. ***Greater attention to erosion-preventing practices in scheduling and operations will benefit water quality and ensure that the Towns have a leg-up on the Municipal Roads General Permit.***

Most capital projects are including water quality measures, though there is room for education of Planning Commissions and the public on the "why" and "how much" of adding stormwater-related costs to road reconstruction projects. The Town of Warren has implemented software for capital planning and budgeting, made equipment purchases, and begun using bank stabilization techniques that are benefiting water quality and municipal operations. While the limitations on equipment sharing are understood, ***there is certainly an opportunity for sharing best practices among road crews.***

In general, great progress has been made upgrading culverts and reducing the potential for storm-related blow-outs. However, ***the most recent culvert and bridge inventory completed by CVRPC contains substantial inaccuracies in some towns where CVRPC crews were not accompanied by a Town staff member knowledgeable about the location and condition of local infrastructure. In these cases, a lack of accuracy is hampering prioritization, planning and maintenance***. Staff in four towns reported problems with the inventory and believe that ***a thorough and accurate update is needed immediately*** to support sound maintenance, budgeting, and planning. However, in the one town where a staff member was dedicated to work with the inventory crew, the accuracy is reported to be excellent and the information very useful. This points out a need for Select Board and town administrative staff to direct road crews accordingly when the inventory is next updated.

Small, localized storms have had devastating effects on portions of the Valley's roadway systems and on the ability of Towns to budget and plan for other capital improvements. Duxbury has been particularly affected by storms on the north side of Camel's Hump. Contingency plans and mutual aid agreements for severe events, whether formal or informal, and identification of areas at greatest risk from the impacts of localized storms, are recommended.

Assessment and Recommendations: A joint, Valley-wide ***working group among road crew and town staff members for sharing information*** about the permit process and compliance strategies may be a helpful way to address the information needs, and share best practices. Continued information sharing on how implementation has worked, and better ***communication with VTrans (both in Montpelier, and at the two District garages serving the Valley) is recommended.***

Updating and enhancing the bridge and culvert inventory, and ensuring its accuracy, is a high priority for all MRV road foremen and staff members, and should be a high priority for the Task Force. Coordination with CVRPC will be important. The Task Force and FMR may wish to consider investigating funding opportunities to expedite this update in advance of, or in coordination with, Ridge to River Program development and implementation.

1.5.2 Addressing Existing Development

With the relatively slow pace of land development and land use change in the Valley, and the issues associated with existing impervious surfaces in the developed landscape noted in the Environmental Assessment, addressing the stormwater runoff impacts of existing development should be considered an area of potential focus in developing a Valley-wide management program. Managing existing conditions is, however, the most challenging area, since it involves modifying sites for which development permission has already been granted, and where investment or redevelopment may not be planned.

Nonetheless, the research in this report has identified two specific opportunities for program development addressing the contribution of existing development, and comparable programs in place elsewhere in the U.S. that provide a starting point for discussing how the Valley could develop programs or projects. It is important to note that there is never perfect transferability among programs, since local budgets, regulations, capacity and conditions always will differ, but these are worthwhile starting points for discussion. These concepts have been captured in the Implementation Matrix as well.

Concept 1. "Pre-emptive" maintenance on erosion- or flooding-prone driveway and culvert areas.

Comparable program: Multiple programs providing restoration and pre-emptive management in flood-prone areas (for example, Milwaukee *Greenseams*[9]; City of San Diego channel maintenance program[10])

Discussion: The Town of Duxbury raised this option in response to the interview question "If money fell out of the sky for stormwater, what would you spend it on?" Some budget allowance, and contractor support, could allow municipal road crews to fix spots that are known to be likely to fail in the event of a heavy rain. This "pre-emptive" practice has paid significant dividends in areas where heavy storms have caused significant damage, including San Diego and metropolitan Milwaukee.

Concept 2. Partnership Funds for Residential Driveway/Culvert Retrofits

Comparable Program: TRPA (Lake Tahoe) Stormwater Management Program[11], Town of Waitsfield Community Wastewater Loan Fund Program

Discussion: Another recommendation from the interview process concerned the potential to provide partnership funding – whether with grants, loans, or a cost share program – to fix residential driveways and culverts that are causing stormwater runoff problems. Road crews reported that budgets of $2,000 to $6,000 per site or intersection could, if available and 'picked off' at a rate of a few per construction season, begin to remedy problem sites. A comparable and highly successful program is the Tahoe Regional Planning Agency's residential BMP retrofit program, under which residential property owners work with trained NRCS representatives to design BMPs to mitigate driveway and impervious surface runoff – and then are required to fund the improvements, or apply for hardship funding. TRPA staff interviewed by the project team over the past several years, along with reports on the program (see footnote) have stated that this program is an unequivocal success and was in fact so popular with property owners, waiting lists had to be generated for BMP design and implementation. The Tahoe program was implemented in response to a stringent sediment TMDL, providing a strong regulatory basis for the program that the Valley is unlikely to have. Program development issues include landowner easements, prioritization, ensuring maintenance, and securing contractor assistance. Nonetheless, creating program framework options and potentially exploring how SRF funds could be revolved through as partial funding, as has been done successfully for the Waitsfield Community Wastewater Loan Fund, might yield an effective way to address retrofits.

1.5.3 Working Lands

In contrast to the state-level regulatory environment for developed lands, the proposed Required Agricultural Practices (RAPs) for agriculture and Accepted Management Practices (AMPs) for forestry stemming from the

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[9] http://www.mmsd.com/floodmanagement/greenseams
[10] https://www.sandiego.gov/stormwater/services/channels
[11] http://tahoebmp.org/

passage of Act 64 ***are likely to substantially affect water quality-related review and enforcement for most agricultural and forestry operations in the Valley***, though the full extent of that impact is not yet clear. Especially for agricultural activities in the MRV, once some of the critical jurisdictional parameters (such as the livestock thresholds for required certification of small farm operations) are better-defined, a path towards offering technical support, tools, and resources supporting these concerns as part of a Valley-wide stormwater management program is anticipated to be more clear.

Continued and close attention to ongoing State-level rule-making and policy development for forestry and agriculture is vital. Valley-wide programmatic stormwater management strategies specific to these land uses offered now, especially with regard to agriculture, run a very real risk of becoming quickly obsolete, alienating the farmer-producer community—or both. Valley-wide programmatic stormwater management ***strategies specific to agricultural or land uses will be better considered later in 2016***, when state-level rule making activities around both these fields are closer to resolution.

There are a number of programs and projects that are available to support owners of working lands in minimizing water quality impacts associated with the operations. Three key opportunities with potential application for the Mad River Valley are described briefly below with links provided to relevant materials:

- **Portable skidder bridges** are a best management practice for controlling non-point source pollution associated with timber harvesting operations. When properly installed, used, and removed, skidder bridges minimize stream bank and stream bed disturbance, reducing the occurrence of sedimentation, channeling, and degradation of aquatic habitat. Portable skidder bridges are also economical because they are reusable, easy to install, and can be transported from job to job. More information on the portable skidder bridge currently being administered in certain parts of the state by local Conservation Districts is available here: http://tinyurl.com/j837hhm
- The **Regional Conservation Partnership Program** (RCPP) promotes coordination between NRCS and its partners to deliver conservation assistance to producers and landowners. NRCS provides technical and financial assistance to producers through partnership agreements and through program contracts or easement agreements in target watersheds. The Memphremagog Long-term Water Quality Partnership was recently awarded $674,000 through RCPP. The Mad River watershed could consider a future applications for funding. More information is available here: http://www.nrcs.usda.gov/wps/portal/nrcs/main/vt/programs/farmbill/rcpp/
- As part of the Lake Champlain Initiative, NRCS has selected four watersheds as water quality focus areas for USDA and its federal, state and local partners. Applications to EQIP and other NRCS funding programs from water quality focus areas receive priority for technical and financial assistance. Water quality focus areas will rotate to new watersheds over time, and the Mad River Valley may wish to pursue this designation.

2. IMPLEMENTATION MATRIX

As summarized in Section 1, the research process – including the interviews detailed in Section 3 and the environmental data assessment presented in Section 4 – identified a significant number of needs and opportunities to increase flood resilience and improve water quality by addressing stormwater runoff. The needs have been organized by land use category and summarized in the matrix which follows. Options and opportunities for addressing each need are also presented and categorized as to whether implementation would be founded in regulatory change, a programmatic effort, a specific project, or some combination thereof. Although not exhaustive, the matrix presents a comprehensive list of potential actions that the Task Force and FMR may wish to pursue. In Phase 2 of this effort, the Project Team will work with the Task Force to refine and prioritize potential actions, including selecting one or more actions for immediate development.

Land Use Category		Existing Water Quality- or Resilience-related Concern	Possible Approach	Approach Type (Regulation, Program or Project)	Source (Env. Data, Interview/ TF, Literature/BPJ)
Developed Land	General	There are 'pieces and parts' of public education on stormwater and watershed resilience, but not a concerted effort to link these different environmental education pieces into a specific, Valley-wide 'push' for education.	Develop a basic "101" public education presentation with the stormwater and resilience-related findings of this study, oriented to the education needs of the elected and appointed boards in the Valley Towns	Project	Interview/TF
			Develop issue- and audience-specific printed materials, such as earth moving activities on residential sites, identifying and reporting erosion control issues or increase public literacy regarding river science and floodplain management practices	Project	Literature/BPJ
			Prepare a video for media engagement on stormwater management, focusing on Valley-specific issue(s) such as earth moving activities on residential sites or identifying and managing erosion	Project	Literature/BPJ
			Prepare a high-quality, Valley-wide stormwater plan	Project	Literature/BPJ
		There are insufficient provisions in existing Vermont and Valley municipal regulations to ensure site-scale land disturbance is minimized during construction	Establish clear standards in municipal bylaws limiting the area and type of vegetative clearing – especially of trees and stream buffer vegetation – and requiring clear demarcation of the limits of disturbance	Regulation (municipal zoning)	Literature/BPJ
		The effects of soil compaction that occurs during construction present a lingering challenge to stormwater infiltration	Establish standards in municipal bylaws requiring protection of vegetated areas and restoration of functional, absorptive landscaping after construction	Regulation (municipal zoning)	Literature/BPJ
		Land disturbing activities in areas with steep slopes and/or more erodible soil types have a higher potential to "unravel" if they are not properly stabilized	Revisit existing standards restricting development density or types of development on steep slopes or in erosion-prone areas, and evaluate how recent applications were managed, including how well existing provisions being applied and followed	Regulation (municipal zoning)	Interview/TF

Land Use Category		Existing Water Quality- or Resilience-related Concern	Possible Approach	Approach Type (Regulation, Program or Project)	Source (Env. Data, Interview/ TF, Literature/BPJ)
		Few projects outside resort areas exceed state regulatory thresholds where a permit is required for construction-related stormwater management (e.g., erosion prevention and sediment control)	Include required construction-phase erosion control standards for site plans, subdivisions, driveway/culverts, public roadway and other land-disturbing projects; review Fayston regulations in light of recent applications	Regulation (municipal zoning)	Env. Data
		Land development regulations are lacking specific technical standards for what erosion control measures and site development limitations should be implemented during construction	Revise existing descriptive standards and/or consider recent practice standards from Fayston and others to incorporate specific, performance-based requirements	Regulation (municipal zoning, associated application forms)	Interview/TF
		With the exception of Fayston and some projects in Warren, land development projects do not require post-construction stormwater control unless under Vermont DEC review	Develop and implement post-construction standards (and review thresholds in Warren and Fayston) setting targets for the quality and quantity of runoff that may leave a site after construction	Regulation (municipal zoning or other ordinance)	Literature/BPJ
			Create clear process for technical review of development plans by a qualified consultant, using Warren as example	Program and Regulation	Literature/BPJ
			Consider requiring bonding or a letter of credit where a development project has the potential to lead to erosion or stormwater management impacts	Regulation (municipal zoning or ordinance)	Literature/BPJ
		Even when (limited) stormwater management measures are incorporated into local permits, there is no guarantee they are built, operated and maintained properly.	Create requirement and staff/contractor capacity to inspect sites before construction commences to ensure erosion control measures are in place and disturbance limits demarcated	Program and Regulation (municipal zoning or ordinance)	Literature/BPJ

Land Use Category		Existing Water Quality- or Resilience-related Concern	Possible Approach	Approach Type (Regulation, Program or Project)	Source (Env. Data, Interview/ TF, Literature/BPJ)
			Inspect sites after significant rainfall to ensure erosion control measures are performing appropriately	Program	Literature/BPJ
			Inspect sites post-construction to ensure site matches plans, including any stormwater controls	Program	Literature/BPJ
		Much of the actual land-disturbing activity in the MRV goes unreported or is not discovered until after damage is done	Develop a simple framework ("see, click, fix") that enables, encourages, and empowers residents to report active erosion sites	Program	Interview/TF
		Snow removal and storage practices do not account for the impact of the melt on water quality	Develop and implement snow storage guidelines for locations and events when snow cannot be managed within the existing roadway.	Program	Literature/BPJ
		Elevated chloride concentrations have adverse impacts on aquatic biota; these effects are often most strongly felt in small streams. Studies in New Hampshire have shown that as much as half of in-stream chloride loads can be traced to private roadways and parking lots.	Develop education and outreach program targeting commercial property owners and managers promoting the importance of controlling salt application.	Program	Literature/BPJ
		Only two of five Valley towns have adopted Fluvial Erosion Hazard (FEH) zoning	Support efforts in Duxbury, Moretown and Fayston to evaluate and consider adoption of FEH zoning or an equivalent	Regulation (municipal zoning)	Interview/TF
		Existing impervious cover datasets for the Valley lack the resolution, coverage, and consistency needed to effectively quantify existing impervious cover or to track changes in impervious cover over time	Work with CVRPC, VANR, UVM SAL or VCGI to create a single, current, high-resolution impervious cover dataset for all Valley towns that can serve as the baseline against which future changes in impervious cover are measured	Project	Env. Data

Land Use Category		Existing Water Quality- or Resilience-related Concern	Possible Approach	Approach Type (Regulation, Program or Project)	Source (Env. Data, Interview/ TF, Literature/BPJ)
		There isn't a coordinated approach carried through MRV Town Plans related to flooding resilience	Complete VNRC's *Resilient Communities Scorecard* or similar for each MRV communities in order to assessment resilience in jet areas including transportation, energy, housing, land use and healthy community design	Project	Literature/BPJ
		Landowners do not fully understand potential, future flood hazards and therefore are unable to incorporate such considerations in project development	Provide background information with the maps that helps the public understand what constitutes a hazard, how hazards were identified for their area, and how to assess the risk posed by that finding.	Program	Literature/BPJ
			Incorporate approaches and standards in local land development regulations to protect vulnerable areas such as floodplains and wetlands that can help reduce flooding and flood damage	Regulation	Literature/BPJ
		Currently available funding is insufficient to support needed stormwater management and resilience activities	Explore funding sources for stormwater management such as s stormwater utility	Program	Interview/TF
	General residential	Projects subject only to zoning permits have few or no specific erosion control requirements	Enhance zoning permit standards, and add to the required information on application forms, to require simplified erosion control for all land disturbing projects	Regulation (municipal zoning & application forms)	Interview/TF
		Capacity to write technically valid, readily enforceable DRB/PC decisions and conditions on erosion control requirements is limited	Collaborate with staff, DRBs, and legal counsel, and provide resources for writing specific and enforceable standards and procedures for erosion control, including measurable standards	Regulation (municipal zoning) and Program	Literature/BPJ
		Zoning Administrators lack support and training to provide effective oversight of erosion control provisions	Provide funds and time for ZAs and DRB members to gain training on erosion control best practices	Program	Interview/TF

Land Use Category		Existing Water Quality- or Resilience-related Concern	Possible Approach	Approach Type (Regulation, Program or Project)	Source (Env. Data, Interview/ TF, Literature/BPJ)
			Establish on-call agreements with local engineers and CPESCs that can be called to provide erosion control oversight	Program	Literature/BPJ
		There is not a consistent approach to small-scale development at the local level that prevents new or additional vulnerabilities along Valley waterways.	Consider a "No Adverse Impact" approach for river corridor and floodplain uses.	Regulation	Literature/BPJ
	Rural residential	The cumulative area of unregulated land-disturbing activities (e.g., quasi-forestry) in rural residential areas is difficult to estimate because it is unregulated and largely inaccessible from public rights-of-way, but it is believed to be a significant source of pollution	Review options and implications for amending municipal zoning bylaws to include a land disturbance permit for any land-disturbing activity (i.e. replacement for zoning permit)	Project and Regulation	Interview/TF
		Driveway and private road openings with steep or geometrically poor angles of intersection, and/or undersized or poorly set driveway culverts, are adversely impacting town roads and drainage networks, in some cases creating hazards during intense storms	Offer technical and/or financial assistance to homeowners to modify intersections with town roads	Program	Interview/TF
			Provide funding for road crews and/or partnership with local contractors to complete "pre-emptive" or proactive maintenance at sites where conditions are likely to cause stormwater problems or culvert failure in significant storms	Program	Interviews/TF
			Update regulations and Town procedures (where needed) to ensure that all development applications with a driveway or	Regulation (municipal ordinance and associated	Interview/TF

Land Use Category		Existing Water Quality- or Resilience-related Concern	Possible Approach	Approach Type (Regulation, Program or Project)	Source (Env. Data, Interview/ TF, Literature/BPJ)
			curb cut are reviewed and signed off on by road foremen, and include erosion control provisions and culvert sizing guidance	engineering standards)	
		Homeowner-led (or completed) efforts to replace culverts, re-grade driveway aprons, add foundation drains, etc. are largely unregulated and have had significant water quality impacts	Education and outreach targeted to contractors and equipment operators, potentially including printed material, workshops or educational videos	Program	Interview/TF; Literature/BPJ
		Improper construction of driveway drainage results in concentrated flows which adversely impact town roads	Offer technical and/or financial assistance to homeowners to improve driveway drainage	Program	Interview/TF
			Update regulations to include minimum standards for driveway drainage, including ditch shaping and stabilization, and maximum flow path lengths between turn-outs	Regulation	Literature/BPJ
	Village residential	Historic or sub-jurisdictional impervious surfaces were, and are, often constructed without proper post-construction stormwater management	Establish community-led retrofit program to fund the construction of stormwater retrofits, potentially using SRF funding as initial implementation funding source	Program	Literature/BPJ
			Establish local standards for stormwater management as part of redevelopment projects that fall beneath existing state jurisdictional thresholds.	Regulation	Literature/BPJ
	Roads and Transportation Related infrastructure	Town plans do not address transportation-related stormwater management in detail, which may disadvantage grant applications	When and as town plans are updated, advocate for and help write road maintenance strategies that emphasize dispersing stormwater (e.g., turnouts) rather than directing flows to streams or other waterways; use recent Moretown Plan as example	Regulation (municipal plan)	Interview/TF

Land Use Category		Existing Water Quality- or Resilience-related Concern	Possible Approach	Approach Type (Regulation, Program or Project)	Source (Env. Data, Interview/ TF, Literature/BPJ)
			Advocate for and help write standards (potentially based on the Better Backroads manual) for infrastructure, such as roadway widths, culvert sizing, grades, drainage system requirements and discharge points, when and as town plans are updated	Regulation (municipal plan, potentially municipal ordinance)	Literature/BPJ
		Project scheduling for road crews does not always leave time for daily close-out	Work with road crews on weather-based scheduling and quick stabilization practices to ensure disturbed sites are stabilized	Project	Interview/TF
			Explore purchase or lease/rental option for hydroseeder (except for Warren) or other equipment that could be used to expedite close-out/site stabilization	Project	Interview/TF
		Capital investments in improved road practices can take time to yield dividends	Education and outreach targeted to Planning Commissions, Select Boards, and taxpayers on the "why" and "how much" of adding stormwater related costs to road reconstruction projects	Program	Interview/TF
			Develop a prioritization tool that gives weight to future climate conditions and risk, and helps focus efforts/investments on areas of highest risk	Project	Literature/BPJ
		Municipal Road General Permit is anticipated to have a significant, although somewhat unknown, impact on municipal operations	Form a Valley-wide working group among road crew and town staff members for information sharing	Program	Interview/TF
			Provide education on VTrans standards and best practices for all Valley planning commissions and select boards, including cost impact of upgraded standards and options for enhanced management programs	Project	Literature/BPJ

Land Use Category		Existing Water Quality- or Resilience-related Concern	Possible Approach	Approach Type (Regulation, Program or Project)	Source (Env. Data, Interview/ TF, Literature/BPJ)
		Each year, localized, intense rain events have had devastating impacts on limited areas of roadway system	Identify and prioritize areas at greatest risk from the impacts of localized storms	Project	Interview/TF
			Develop mutual-aid style inter-municipal agreements between Valley towns, similar to Duxbury's agreement with Bolton	Program	Interview/TF
			Establish on-call agreements with local contractors that can be activated following a flood event	Program	Interview/TF
		Undersized and failing culverts pose risk to road network	Develop and apply criteria to prioritize and rank culverts for replacement	Project	Interview/TF
			Initiate scoping for specific culvert replacement projects identified in each Town	Project	Interview/TF
			Develop 5-year road maintenance plan that integrates culvert replacement projects with road improvement projects	Program	Literature/BPJ
			Require repair/replacement of both publicly owned and private culverts if Road Foreman determines adverse impacts are occurring on Town roadway system	Program	Literature/BPJ
		Most recent CVRPC culvert and bridge inventory contains inaccuracies	Update inventory as soon as possible	Project	Interview/TF
		Gravel roads in some locations may have greater water quality impacts than would occur if segments were paved	Conduct stormwater runoff modeling and prepare cost estimates for candidate segments	Project	Interview/TF

Land Use Category		Existing Water Quality- or Resilience-related Concern	Possible Approach	Approach Type (Regulation, Program or Project)	Source (Env. Data, Interview/ TF, Literature/BPJ)
		Current long-term capital project planning efforts are limited, and complicated by uncertainty related to construction season length and conditions, necessary appropriations, and severe storms and flood events	In the municipal budget development process, explore potential to purchase and implement capital planning/budgeting software such as RMS11, and allocate staff time and resources for training and use	Project	Interview/TF
			In the municipal budget process and as the Municipal Roads Permit is developed, define overall goals and objectives using a multi-year planning horizon, which can be used to guide adjustments to the capital plan in light of year-to-year variations	Project	Literature/BPJ; Interviews/TF
		Landowners or their contractors replace culverts or modify driveway aprons without technical assistance from Road Foreman	Provide outreach and best practices education to contractors and equipment operators (including those who rent equipment) on culvert and driveway standards	Program	Literature/BPJ
		Ability to secure locally enough rock and gravel to meet the enhanced VTrans maintenance standards and keep up with extreme storm damage is becoming difficult	Evaluate local gravel resources and establish buying agreements.	Project	Interviews/TF; Literature/BPJ
		Several subwatersheds in the Mad River Valley have road-stream crossing densities well over 1.3 per km^2, which, in some cases in Chittenden County, were also associated with increased nutrient and sediment levels.	Develop a suite of best management practices specific to road-stream crossings and prioritize implementation in watersheds with the highest densities; consider targeting these areas for a roadway or residential property retrofit program (described above)	Project	Env. Data
		Several subwatersheds in the Mad River Valley have road densities of 2.2 km/ km^2, which, in some cases in Chittenden County, were also	Consider incorporating "road density" as a criterion that is factored into long-term capital project planning, potentially giving more weight to projects in watersheds with higher road	Program/Regulation (higher standards in	Env. Data; Literature/BPJ

Land Use Category		Existing Water Quality- or Resilience-related Concern	Possible Approach	Approach Type (Regulation, Program or Project)	Source (Env. Data, Interview/TF, Literature/BPJ)
		associated with increased nutrient and sediment levels.	densities; consider whether enhanced stormwater management standards are needed in zoning for these subwatersheds.	zoning for specific subwatersheds)	
		Cumulative length of private driveways is nearly half again the total length of municipal roads in the Valley	Evaluate opportunities to encourage shared driveways through changes in local zoning	Regulation (municipal zoning)	Env. Data
		Nearly 40% of private driveway miles have slopes in excess of 15%	Review Fayston's standards for driveways with steeper slopes and consider adopting specific approval standards and conditions for driveway slopes proposed in excess of 10%	Regulation (municipal zoning)	Env. Data
	Resort areas	Gravel parking lots at ski areas are a highly visible potential source of sediment pollution	Work with ski areas to improve management of parking lot runoff and create publicly-visible green infrastructure BMPs	Project	Interview/TF
		Areas of ski resorts built prior to 2002 include significant areas of impervious surfaces without modern stormwater management	Partner with resorts to pursue funding for the construction of stormwater retrofits	Project	Interview/TF
		Standard practice for managing water on ski trails is to have a series of water bars running perpendicular to the ski trail with frequency dependent on the steepness of the trail. Are there other, newer practices that better manage water?	Identify and pilot potential management approaches for water on ski trails	Project	Interview/TF
Forestry and Forest Lands	Silviculture	The National Land Cover Dataset (NLCD) shows a loss in forest cover between 2001 and 2011	At the planning commission or MRVPD level, evaluate and understand the drivers of this significant change in land cover by town and consider potential regulatory, land conservation, or voluntary responses	Project	Env. Data

Land Use Category		Existing Water Quality- or Resilience-related Concern	Possible Approach	Approach Type (Regulation, Program or Project)	Source (Env. Data, Interview/ TF, Literature/BPJ)
			Adopt tree canopy protection measures designed to promote no net loss of tree canopy through protection or larger existing trees and/or replacement at a 1:1 caliper basis	Regulation	Literature/BPJ
		Logging trucks have significant, adverse impacts on local roads and are not able to be regulated by the municipality with responsibility for the roadways	Consider incorporating "heavy use" as a criterion that is factored into long-term capital project planning for town roads, potentially giving more weight to projects on roads with heavy use	Project	Interview/TF
		Silvicultural activities tend to occur in sensitive (headwaters) areas of the watershed and therefore can have a disproportionate impact	Revisions to Vermont AMPs include significant improvements in practices for stream crossings, and for the stabilization of log landings during and after logging; it will be important to designate a Valley task force to track progress as revised AMPs are implemented and to re-assess the options for further reducing this impact	Project	Literature/BPJ
			Promote and demonstrate the use of portable bridge designs on timber harvesting operations	Program	Literature/BPJ
	Recreational Trails	Recreational trails often lack formal/professional maintenance and oversight	Develop and distribute targeted education and outreach materials on techniques for managing runoff from and around trails (such as "reverse grade dips" that allow water to exit the trail)	Project	Interview/TF
		Available trails data provide a partial representation of the Mad River Valley's trail network and no data are available regarding the current conditions of the trail network; taken together this lack of data makes assessment nearly impossible	Undertake qualitative assessment, including field surveys as possible, of the importance of recreational trails in Valley water quality, and the prevalence of water quality issues along the trail network, in order to evaluate value of additional and more intensive data collection	Project	Env. data

Land Use Category		Existing Water Quality- or Resilience-related Concern	Possible Approach	Approach Type (Regulation, Program or Project)	Source (Env. Data, Interview/ TF, Literature/BPJ)
Agriculture	Cropland and Pasture	Agricultural drainage (e.g., ditches) sometimes bypasses buffers and compromises intended water quality benefits	Through cooperative projects and grant funded demonstrations, promote two-stage channel design which incorporates benches that function as buffers and floodplains within the ditch footprint	Project	Interview/TF
		Lack of agreement on the width and composition of buffers	Evaluate whether revisions to RAPs which will require 25-foot buffers on surface water and 10-foot buffers on ditches are sufficient to meet water quality goals	Project	Interview/TF
		Concentrated flows on/from upland, sloping fields can result in significant rill and gully erosion	Through outreach and demonstration projects, work with participating farmers to promote the installation of grassed waterways to provide safe conveyance of concentrated runoff to surface waters	Project	Interview/TF
		There are 608 acres of active agricultural land (or 0.6% of the Mad River's watershed area) located within close proximity to water resources (including floodplain or river corridor)	Target outreach and implementation of conservation practice programs to agricultural producers and landowners located in close proximity to water resources	Program	Env. Data
		Total agricultural land cover with potential erosion indicators as a percentage of sub-watershed area may be a useful indicator of a priority area for focus; only a few sub-watersheds have more than 3% of total sub-watershed area with one or more indicators	Use watershed modeling approaches, as well as field observations, to identify individual farm fields that represent a disproportionate risk to water quality (e.g., critical source areas)	Project	Env. Data
		Agricultural lands are conserved in a manner designed to protect the working landscape, but do not necessarily maximize opportunities to enhance resilience	Work with land conservation organizations active in the Valley to incorporate resilience (e.g., stormwater absorption, river channel adjustment) into selection processes and/or provision of other incentives to local farmers	Program	Literature/BPJ

Land Use Category		Existing Water Quality- or Resilience-related Concern	Possible Approach	Approach Type (Regulation, Program or Project)	Source (Env. Data, Interview/ TF, Literature/BPJ)
	Farmsteads	Draft RAPs may give towns some authority to manage more than farm structures (meaning manure management, etc.) at "very small agricultural operations" through local zoning	Track and evaluate authorities available to towns to regulate agricultural operations as RAPs are implemented	Regulation (municipal zoning)	Literature/BPJ
		Allowing livestock to have direct access to surface waters causes water pollution via "direct discharges", as well as trampling and damage to stream and riverbanks	Track and evaluate livestock exclusion requirements contained in the RAPs; current draft allow access only at defined crossings and defined watering areas	Regulation	Literature/BPJ
		New requirements for storing dry stacked manure will be challenging for small farms to implement	Support and connect small farms with resources available through AAFM and NRCS to improve manure stacking; consider providing a website with links to resources, photos and other assistance.	Project	Interview/TF
		Stormwater runoff tends to flow along and follow paths, roads, and animal trails	Partner with farmers to access funding for improvements to animal trails and walkways available through NRCS; consider a field day for public engagement if there is a cooperating landowner	Project	Interview/TF

3. TECHNICAL REPORT: POLICY

3.1 Introduction

The steps in the policy research process were completed over a six-month period from roughly October, 2015 through March, 2016.

1. The ***Kick-Off Discussion*** held in September, which included an initial discussion of particular priorities, examples, concerns, or "war stories" related to stormwater management. This discussion helped focus the team's research and the interview questions that were submitted to and reviewed by FMR.
2. A ***review of existing plans, policies and bylaws*** related to the condition of Valley's watersheds and surface waters. This review, and the context provided by interviews with Valley Planning Commission, Development Review Board (DRB) members, and staff, evaluated existing planning, zoning, and subdivision regulations and ordinances in each Town to understand their effectiveness in managing stormwater runoff and protecting stream corridors
3. ***Interviews with "boots on the ground" in the Valley involved in land use, municipal management, road crews, agriculture, and forestry***. The questions were framed towards drawing out perspectives on where existing systems and policies work and where individuals feel improvement is needed, while also keeping in mind possible future state-level regulatory requirements (such as the potential decrease in permitting threshold for post-development stormwater management, or the forthcoming municipal roads general permit program).

3.1.1 Regulatory Review & Stakeholder Interview Process

The team gathered information and insights from municipal staff and elected/appointed officials on the actions and policies that, taken together, comprise a municipality's "toolkit" for addressing stormwater management. The goal was to understand the current status of those specific areas of development review, enforcement, planning, maintenance and regulation that address stormwater management. The scope and quality of the conversations, and the candor of the participants, yielded practical, actionable information for an ongoing Valley stormwater program. The participants are listed below.

DUXBURY: John Murphy, Select Board; Al Quesnel, Zoning Administrator; Adam Magee, Road Foreman; Alan Quackenbush & members of the Planning Commission; Will Senning, DRB; Brian Fitzgerald, Planning Commission.

FAYSTON: Jared Cadwell, Select Board; Carol Chamberlin, Planning Commission; John Weir, Zoning Administrator; Stuart Hallstrom, Road Foreman.

MORETOWN: John Hoogenboom, Select Board; Karen Horn & members of the Planning Commission; John Weir, Zoning Administrator; Ben Falk, Whole Systems Design; Eric Howes, Fire Warden and farmer. *Not included*: Martin Cameron, Road Foreman.

WAITSFIELD: Sal Spinosa, Select Board; Brian Shupe, DRB; Valerie Capels, Town Administrator; Susan Senning, Zoning Administrator; Rodney Jones, Road Foreman; Elwin Neill, Neill Farm.

WARREN: Bob Ackland, Select Board; Rae Weston, Road Foreman; Cindi Hartshorn-Jones, Select Board Assistant; Barry Simpson, Public Works Director; Miron Malboeuf, Zoning Administrator.

STAKEHOLDERS: Margo Wade, Sugarbush Resort; Robin Morris, Vince Gauthier, Mad River Food Hub/Irasville Business Incubator; Lisa Loomis, The Valley Reporter; Peter Lazorchak, PE, Wilcox & Barton.

3.2 Land Development: Regulations, Development Review and Zoning Administration

Task 2 of this project was a review of the regulations and permitting in place in the Valley around *land development*: Those land-disturbing activities (other than roadway construction, maintenance and repair) that may require review by the State of Vermont, a municipal Development Review Board or a Zoning Administrator, and those land-disturbing activities that are exempt from local review. Birchline Planning LLC (Birchline), as part of the Stone team, reviewed the local regulations that are summarized in this section. However, the language in the regulations and policies themselves tell only part of the story of where and how water quality-related actions are addressed in each Town. To understand how these regulations are being applied in practice, and how municipal staff and boards are applying the standards in practice, Birchline spoke at length with Development Review Board (DRB) and Planning Commission (PC) members, Zoning Administrators (ZAs), and recent applicants or applicants' engineers who have experience with development review in each Town.

This Section presents first Birchline's review of the content of the regulations and policies, and then the descriptions from officials, applicants and Town staff of how the regulations are being applied in practice. A number of different, potential follow-up steps are noted, some of which take the form of regulatory changes and many of which would involve non-regulatory strategies such as targeted outreach to equipment operators and contractors, citizen training on spotting potential stormwater issues, and enhanced communication among and between ZAs in the Valley towns. It is hoped that this context form the report will help FMR and the Task Force frame future recommendations and action steps.

3.2.1 Applicability of Development Regulations to Land Development Activity in the Mad River Valley

Perhaps the most important context for this task is the degree to which land disturbance and development is covered by the bylaws and regulations in place either at the municipal or state level, and the amount and nature of development review actually taking place in the Valley towns today. Four trends are especially important to this discussion:

1. In the past several years, ***there has been very little land development in the Mad River Valley towns that requires Act 250 review and/or Vermont DEC construction-phase and operational stormwater permitting***. Other than phases of the base area reconstruction at Sugarbush Resort in Warren, and a handful of subdivisions, Act 250 reviews over the past ten years in the five towns have chiefly involved minor amendments, changes of use of buildings, or other administrative amendments rather than new development. Thus, other than forestry activities or issues within the regulated floodplain, Vermont regulations have little impact on how stormwater management and erosion control are reviewed and regulated in the Valley. In this development climate, municipal regulations and especially enforcement assume even greater importance since very little can be addressed by "leaving it to the State."
2. While regulations in the Valley towns do not, as discussed below, prohibit or discourage Low Impact Development (LID) or "green infrastructure" stormwater approaches, ***there are relatively few situations – other than the ski areas – where LID BMPs would be implemented during new construction as a result of requirements contained in local land development regulations***. The very limited scope of land development activity within the Valley other than single-family residential, as described in (1) above, limits the potential impact and benefit of concentrating substantial effort on regulatory review or creating incentives for implementation of LID during development projects. LID regulations and practices such as parking lot bioretention areas, permeable surfacing for parking stalls, or planter boxes for roof downspouts generally are applied to commercial, institutional, or multi-family residential sites. The number and scope of these sites, and the amount of land area in the Valley where such uses could even be permitted under zoning, is limited to ski area development; to the Village centers in Waitsfield Village, Irasville, and Warren; to a lesser extent to Moretown's village; and only to a few sites in Duxbury. In contrast, there is much more low-density residential development and smaller site development or alteration activity that has been identified by stakeholders as having impacts on water quality. Focusing on practices that can deal with residential and small-scale erosion, rather than developing detailed LID regulations for development types that will occur rarely if ever, would direct resources toward a widespread and persistent source of water quality and resilience-related issues.
3. With the exception of Moretown, ***the amount of subdivision and new residential construction activity has tapered off*** since 2006 – and dramatically so since the high growth period of the mid- to late 1990s. Of the Valley towns, Moretown (which presently does not have subdivision regulations in place) saw the most subdivision applications (6) and permits issued for new single-family residences (11) in 2014. Waitsfield had no major subdivision applications and 6 new single-family residential permits; Warren issued 6 permits for new single-family and received 3 subdivision applications, all of which were renewals rather than new applications.
4. ***Site and subdivision applications are almost universally being prepared by licensed professional engineers*** experienced with at least basic aspects of stormwater management and erosion control, and

curb cut designs are being reviewed by Town road foremen – a substantial change from past practice in the Valley, and one that has reduced water quality impacts.

3.2.2 Plans, Bylaws, and Standards in Place in the MRV

Birchline also took the lead in reviewing plans and bylaws in place in the Valley Towns. Along with zoning and subdivision regulations, we noted the status of adoption of the VTrans Municipal Road and Bridge Standards (all five towns have adopted these) and whether a Winter Roads Policy had been adopted, along with other relevant policies or guidelines. Several updates are in progress, notably Moretown's work to implement more robust subdivision regulations, Duxbury's comprehensive update of its zoning that will begin in April 2016, and Fayston's review of its own regulations. Table 1 shows the status of these regulations in the five Towns and as applicable, the effective date of adoption.

Table 1. Plans and bylaws in place, and effective dates

	Town Plan	Zoning/ LDRs	Subdivision	Flood Hazard/ FEH Overlay	Curb Cut Policy	Winter Roads Policy	Hazard/ Disaster Mitigation
Duxbury	Town Plan, 10/27/2014	Zoning Regulations, 1/31/2011; UPDATE IN PROGRESS		Flood Hazard Overlay District in Zoning	Permit & review process	Winter Maintenance Plan & Policy, October 2013	Hazard Mitigation Plan Update, September 2012
Fayston	Town Plan, October 2014	Land Use Regulations, 12/13/2011; review in process		Flood Hazard Overlay District in LURs	Permit & review process	Winter Operations Policy, 1/26/2015	Hazard Mitigation Plan Update, December 2011
Moretown	Town Plan approved 1/4/2016	Zoning Regulations, 9/14/76; multiple amendments, interim section in place	Not in place; Proposed regulations in progress as of 1/5/2016	Flood Hazard Overlay, most recent amendment 3/4/2008	Permit for access to Town highways		Hazard Mitigation Plan Update, January 2012
Waitsfield	Town Plan, 10/22/2012	Zoning, 5/17/2010	Subdivision, 1/21/2008	Flood Hazard Overlay District; FEH Overlay District	Curb Cut Policy, 12/12/2011; permit & review process	Winter Maintenance Plan & Policy, 11/26/2007; Scenic Roads Enhancement & Protection	Pre-Disaster Mitigation Plan, September 2010

	Town Plan	Zoning/ LDRs	Subdivision	Flood Hazard/ FEH Overlay	Curb Cut Policy	Winter Roads Policy	Hazard/ Disaster Mitigation
						Plan, 10/9/2006	
Warren	Town Plan, 4/26/2011; Energy chapter updated 9/22/2015	Land Use & Development Regulations 3/25/2008, multiple amendments		Flood Hazard Overlay District 9/14/2010; FEH Overlay 11/12/2013	Reviewed through zoning permit	Winter Road Maintenance Policy, 12/9/2008	Hazard Mitigation Plan, 3/11/2013

3.2.3 Plan/Bylaw/Policy Content Relative to Water Quality

The review of bylaws, plans and policies was intended to answer the question of what existing documents and regulations say that supports three goals:

- Keeping soil on land: Regulations, plans and policies that reduce the potential for soil instability and the overland transport of sediment.
- Keeping (more) water in soil: Regulations, plans and policies that prevent soil compaction, enhance tree canopy, and conserve and enhance vegetative cover
- Having resilient systems: Incorporating features that both prevent damage from flooding and over-land stormwater flows, and enable communities to bounce back more quickly when flooding or erosive flows occur.

Municipal regulations that would implement these three goals are:

1. Standards limiting the area and type of vegetative clearing – especially of trees, and of stream buffer vegetation – and requiring the installation of functional, absorptive landscaping after construction
2. Standards limiting construction on steep slopes or in erosion-prone areas
3. Construction-phase erosion control standards for site plans, subdivisions, public roadway and other projects, land clearing or disturbance, and construction of other structures
4. Post-construction standards dictating how much runoff may leave a site after construction or disturbance, and what may be contained in that water
5. Standards for infrastructure, such as roadway widths, culvert sizing, grades, drainage systems, and discharge points
6. Town Plan policies supporting adoption and implementation of the standards in 1-5 above.

As noted in Section 1.3, language in bylaws is only as effective as its application by DRBs and ZAs – particularly in the language, specificity, and enforceability of the standards, and any conditions that are imposed – and subsequent enforcement if and when violations occur. Nonetheless, policies and language must be in place both to express the importance of water quality issues to municipalities, and to provide a basis for application and enforcement of these measures. The status of key parameters around water quality for various policies and plans, along with notes and observations, is summarized in the matrix on the next page, and in the sections that follow.

	Duxbury	Fayston	Moretown	Waitsfield	Warren
Limits of disturbance + new landscaping	√	√+	√-	√	√
Limitations on steep slopes & hazard areas	√+	√+	o	√+	√+
Construction phase erosion control	√	√+★	o	√-	√+
Infrastructure standards	√+	√+	√-	√+	√+
Town Plan policies: development	√	√+	√+	√+	√+
Town Plan policies: roadway network	o	√+★	o	o	o

o = minimal or no standards in place
√- = some language in place, minimal/no connection to water quality or specific standards
√ = language in place, standards general, potential application/enforcement challenges
√+ = language in place; standards provide more specificity, better basis for application/enforcement
√+★ = clear language and standards; more easily understood, enforced

3.2.4 Town Plan Language

All of the Valley towns have some language in the Town plan supporting regulations and review processes that address erosion and stormwater management. Moretown's newly adopted plan has an extensive discussion in Section 3, noting that "…there are no standards or guidance for stormwater management provided within the regulations" (p. 24), and contains two very specific recommendations (A-9 and A-10, discussed below) to address this issue. Elsewhere, most of the "stormwater language" concerns preventing impacts from land development. Duxbury's plan does not discuss development or transportation-related "stormwater" *per se*, but rather erosion, with a focus on flooding hazards. Examples of language are shown in the text box at right.

Regarding Fluvial Erosion Hazard areas, which are related to stormwater management, the Duxbury, Moretown and Fayston Town Plans call for further evaluation and consideration of adoption of FEH zoning. FEH overlays are in place in Waitsfield and Warren.

Town of Fayston: Objective 3-4, d. - Require proper stormwater runoff and erosion control measures during construction and on-going maintenance of the development.

What is notable is that the Town Plan policies in place do not include language or policy around the water quality impacts of Town roads and the transportation system. Fayston's Town Plan, the only exception to this statement, States in Objective 3-3 "c. Promote road maintenance strategies that disperse stormwater rather than directing flows into streams and other waterways." As Town Plans are amended or readopted, this is an area where greater attention to policies and goals would be very beneficial.

3.2.5 Relevant Provisions in Land Development Regulations

On a Valley-wide basis, the regulatory situation may best be described as having many ***general and descriptive*** standards in place regarding erosion control, minimizing vegetative clearing, protecting soil structure, and ensuring proper post-construction stormwater control, but ***far less in the way of specific technical standards*** for what erosion control, site development limitations (i.e. clearing and excavation limits, etc.) and post-construction stormwater control measures should be implemented, where, and at what points during construction. None of the Valley towns' regulations in place currently contain specific volume or water quality standards for post-construction stormwater management; therefore, only projects going through Vermont DEC review are required to meet specific engineering requirements for volume or pollutant control. This makes the application of the standards much more challenging during development review and for enforcement. As such, the regulations and standards in place, and the level of knowledge of Development Review Board or Planning Commission members, and Zoning Administrators, provides general, but not necessarily comprehensive, scrutiny, and leaves much to the discretion of the applicant, Board or ZA.

The primary exception to this statement is in Fayston, where Section 3.4 (Erosion and Sediment Control and Stormwater Management) makes all development requiring a municipal land use permit, and forestry operations, subject to specific standards for erosion control planning – using the State's low-risk site handbook as a guide – and standards for disturbance. In addition to the provisions of Section 3.4, conditional uses are required to "…incorporate accepted stormwater management and erosion control practices as appropriate for the setting, scale and intensity of the existing and planned development" (5.4B). The Road Standards in 6.4(E) require "A storm water drainage system shall be provided that is designed to control and manage storm water collected on all proposed roads and/or parking areas in accordance with Section 6.5 of these regulations. Generally, roadbeds, shoulders, ditches and culverts shall be designed and maintained in conformance with the Vermont Better Backroads Manual, as most recently amended." Low Impact Development standards for post-construction stormwater control also are adopted, though as discussed in detail previously, the types of development to which these would likely apply are unlikely to occur in Fayston given the Town's land use pattern, topography, location, and zoning—all of which limit opportunities for the types of commercial, multi-family, and institutional uses that are suitable for the application of most types of structural green infrastructure practices.

Examples of the type of descriptive standard that generally is in place drawn from MRV towns' zoning regulations, and the types of issues that are raised by this approach to regulation, are shown in the tables below:

Example 1.

Regulatory Language in Adopted Zoning	Questions and Specifics
Existing drainage patterns and vegetation will be retained and protected to avoid altering or relocating natural drainage ways	What stream order constitutes a "drainage pattern" to be "protected"? Ephemeral, perennial?
…and to avoid increases in the amount of stormwater runoff being discharged into drainage ways as a result of site compaction,	Is the standard to keep the pre- and post-construction runoff volumes the same? For what design storm?
… the unnecessary removal of vegetative cover,	What is the standard for deciding how much is "necessary" and where vegetation can be removed?
… or re-contouring the land surface. Any proposed regrading will blend in with the natural contours and undulations of the land.	How much grading is allowable, and where? What constitutes "blending in"?

Example 2.

Regulatory Language in Adopted Zoning	Questions and Specifics
Adequacy of landscaping, screening and setbacks with regard to achieving the maximum compatibility and protection of the adjacent properties	How much is "adequate"? Must landscaping be opaque upon installation, within one year, within three years?
Particular consideration may be given to the preservation of existing vegetation	How much existing vegetation must be preserved?
…and the suitability of landscaping materials to meet seasonal and soil conditions.	Who is reviewing landscaping materials for suitability?

3.2.6 Technical Review, Bonding, and Inspections

Three potentially effective measures that are perhaps under-utilized in the Valley and could address some of these issues are:

Technical review of plans, in which an applicant pays for an independent review of her/his plan by a qualified consultant, who is hired by and reports back to the Planning Commission or DRB. Charging applicants for technical review of applications is authorized under 24 VSA § 117. Warren specifically authorizes the DRB to require technical review of grading and erosion prevention control plans in Section 9.8(D) of its Land Use and Development Regulations, but interviews with DRB and Planning Commission members elsewhere indicates that this option is not often used. With Select Board support, using technical review for erosion control and stormwater management would ensure the Towns had access to qualified support on stormwater management issues.

Bonding/letters of credit. Where a development project has the potential to lead to erosion and stormwater management impacts if not constructed properly, as on particularly sensitive sites, municipalities often will hold a bond or letter of credit from an applicant to ensure that erosion control measures, post-construction stormwater controls, and landscaping are properly installed and that landscaping takes root. None of the stakeholders interviewed recalled a case where a bond or letter of credit had been held, but in at least one instance, a contractor had been reluctant to complete retroactive erosion control measures because of cost. This may be a useful strategy if and when a particularly complex project is proposed, or if there are potential impacts on water resources, adjacent properties, or Town resources if landscaping, erosion control or post-construction controls are not implemented properly. A typical duration for a letter of credit for landscaping is three years; bonds generally can be released after a post-construction inspection is completed.

Inspections. There are few specifications for periodic inspections during or after construction. The recommended practice for inspections related to stormwater and water quality is to inspect before construction commences, to ensure erosion control measures and in place and limits of disturbance and on-site storage areas are demarcated; during construction and after substantial rainfall, to ensure erosion control measures are performing appropriately, limits of disturbance are still in place, and any post-construction controls are being constructed; and at the close of construction, to ensure that the post-construction site matches the plans. Since staff time is limited, in many cases municipalities will either contract inspections at the applicant's expense, or allow the applicant's engineer to certify inspections at each point. The key is to be specific about when inspections shall occur, and what particular components must be in place at each point.

3.3 Activities Affecting Water Quality, but not Subject to Land Development Regulations

One of the more important findings of this process has been the great extent to which activities that are not subject to any municipal land development regulations or permit oversight are known to be affecting water quality. In discussions throughout the Valley, these issues were raised repeatedly. When Select Board members were asked how their Boards approached these types of issues, only three instances were noted where members recalled a Board taking action on a water quality-related issue outside major infrastructure projects such as the water and wastewater systems, or a road reconstruction.

1. ***Clearing of wooded lots and "quasi-forestry"***. In many cases, landowners or contracted foresters are undertaking clearing of wooded lots that "isn't quite forestry," and yet is not done in the context of a permitted construction project or subdivision. ZAs noted that without the authority for minimal oversight or even notice of these types of activities, erosion-prone sites can be created that affect adjacent properties, streams, and roadway networks.
2. ***Erosion control on individual, small development sites with zoning permits only***. As noted throughout this report, projects subject only to zoning permits have few or no erosion control requirements other than recommendations that proper practices be followed. ZAs did report a handful of instances of enforcement actions around erosion issues, many of which were successfully resolved through thoughtful and well-timed communication by the ZA. This is perhaps the greatest area of opportunity for regulation, enforcement and communication to have a direct and beneficial impact on stormwater management and water quality in the Valley towns.
3. ***Culvert removal/replacement by landowners or contractors***. Another relatively frequent activity that may or may not require a permit is removal and replacement of driveway culverts. In cases where landowners or their contractors replace culverts or modify driveway aprons, damage to Town roads, erosion from land disturbance, or erosive flows can occur. ZAs stated that the level of expertise and care varies among contractors, and that many landowners own and use earth-moving equipment for these kinds of projects, making this a headache for enforcement especially when it is a grey area in regulations. As one noted, "It would be outstanding to license and train all equipment operators in Vermont on these practices."
4. ***Enforcement is sporadic and challenging***. ZAs, as well as some PC and DRB members and Town staff members, noted that while subdivision and site plan permits typically are written with conditions requiring general erosion control, enforcement capacity is limited. As described above, enforcement relies on periodic inspections of sites at key points during the construction phasing process, and evaluation of on-site controls (e.g. demarcation of limits of disturbance, protection of access points, etc.) against an approved erosion control plan. Staff capacity and knowledge on these measures is limited in the Valley, and limited by the relatively small number of sites subject to DRB-imposed conditions.

3.3.1 Recommendations for Phase 2

With respect to regulations and policies, the research done as part of this Task points to a pressing need to address land disturbance at all scales, to adopt more specific erosion control requirements and standards, and to ensure that there is consistent and informed enforcement. This is not an easy discussion, and any answers will have cost, political, and administrative implications. A focus on how land disturbance is treated, and what specific measures are both beneficial to water quality and realistic to enforce, is recommended.

3.4 Town Road Maintenance

Throughout the stakeholder interview process, both municipal participants and other stakeholders – notably Sugarbush Resort, which owns and operates its own roadway system – recognized the tremendous impacts on water quality and stormwater runoff from the Valley's road networks and transportation systems. Unlike land development, which happens sporadically and whose post-construction impacts can be controlled with stormwater BMPs, roadway use and maintenance is a continuous, year-round activity with on-going impacts on waterways. All of the Valley towns also are dealing with the periodic and unpredictable impacts of severe storms. The number and severity of storms in the past 20 years has put a very fine point on the relationship between the transportation system and the watershed. Indeed, all of the roadway system's components – roadway surfaces, drainage ditches, culverts and bridges, and driveway curb cuts – are well understood to be part and parcel of the Valley's stormwater conveyance and watershed systems.

Recognizing this inter-relationship, the General Assembly directed the issuance of a general permit for Municipal Roads. Beginning in 2018, Vermont municipalities must file for coverage under this general permit, meaning in a nutshell that each municipality will need to present a plan of activities that will minimize erosion and water quality impacts from its public roadway system. As of this date much is unknown about the specific requirements for these plans, leading to great concern among staff in the Valley towns about prospective costs for fees and capital projects, demands on staff time, and required changes to maintenance practices that have already had to be updated and changed substantially from past practices.

In this context, the interview and research process in this project provides an excellent opportunity for the Valley towns to assess, individually and collectively, the baseline of water quality-related practices heading into the general permit process. This section summarizes current practices, concerns and issues related to five topics: Maintenance practices; management of curb cuts, culverts and bridges; capital project planning; and program administration. A finding related to all five of these areas bears emphasis: Municipal staff see a pressing, immediate ***need to educate residents and taxpayers, and in many cases their appointed officials as well, about the real life, per-unit costs of good roadway maintenance, water quality-friendly practices, preventive measures, and emergency repairs***. This is an important finding and recommendation from the process.

3.4.1 Maintenance Practices

Maintenance practices in all of the Valley towns have undergone substantial change in the past 10 to 15 years. ***All five Valley towns have adopted the Vermont Agency of Transportation Municipal Road and Bridge Standards***. The principal impact of this policy change affects ditching. Towns are stone-lining ditches, which has added expense to Town budgets. Asked to provide a figure for how much more this costs, one road foreman estimated 10% of the total budget, but stated it is not particularly easy to break out on an overall basis. Securing enough rock and gravel to meet the enhanced VTrans maintenance standards, and to keep up with extreme storm damage and wash-outs, is a concern Valley-wide. With the closing of gravel pits and limits on gravel extraction, gravel and stone have become more expensive and more difficult to secure.

There are some important differences of opinion on the appropriateness of some of the VTrans standards and practices – particularly the use of plastic culverts and some aspects of ditch shaping and maintenance. Road foremen were not at all satisfied with the performance of plastic culverts installed after Tropical Storm Irene (these culverts have been prone to collapse) and expressed a strong desire to replace these as soon as possible. In addition, all of the road foremen stated that there should be more flexibility in shaping side slopes of ditches to deal with bedrock-limited areas and to facilitate clean-outs.

There is frustration about managing the impacts of logging trucks from lands not under town control on the roadway network. As noted in Section 3.6, the location and nature of logging and forestry activities is one of the least well understood and least well mapped pieces of environmental information in Vermont, despite the significant impacts of heavy trucks on town roads. Among the many issues raised during the stakeholder interview process, this is currently one of the least readily addressed and most frustrating to town crews.

Asked about their best sources of information for maintenance or dealing with VTrans policy, there was a split in opinions about the helpfulness of the two VTrans District garages that now serve the Valley. Some staff felt that support was solid and helpful, while others have not had a good experience. The Better Backroads program and Friends of the Mad River were cited as helpful partners and information sources; FMR was especially called out for its partnership and help identifying and securing funds for several capital projects.

Some "common-sense" maintenance practices, such as scheduling project work to ensure construction sites are closed up before the end of the workday and not opening sites when substantial rain is forecast, were generally – but not always – observed by town crews. Rodney Jones in Waitsfield was particularly clear about the importance of giving these directions to crews to ensure "good housekeeping" is consistently observed. Verifying that this type of day-to-day policy and management strategy is in place, and being observed, is likely to be a condition in the Municipal Road Permit; making sure that Valley crews are ahead of it, and documenting these work practices, will give all of the Towns a leg up on the permit submittals.

The Town of Warren had the most to say about its innovations in maintenance practices, and how these have been put into practice. The Town has purchased a hydro-seeder for stabilization, and has been using a bank stabilization technique involving directional drilling that is showing great promise and much better results than conventional rip-rap. Rae Weston put the Town's approach as "We decided we'd try some new things out;" in addition, Town staff uniformly stated that the Select Board and voters have a good understanding how much road maintenance and capital projects cost, and are willing to pay for it. Fayston and Duxbury voters and Select Board members also were described as having a good understanding of costs on the whole, and have approved equipment upgrades and new staff.

3.4.2 Management of Curb Cuts, Culverts, and Bridges

Municipal management of curb cuts, culverts and bridges has progressed substantially in the Valley over the past ten years. With one exception, all of the Towns report that applications for driveways and curb cuts are being reviewed by road foremen, with much more feedback on design, grading and culvert standards. The fact that most development applications (including applications for subdivisions in Moretown, which currently does not have full-blown subdivision regulations) are being prepared by licensed professional engineers with a good working knowledge of best practices has, according to ZAs and road crews alike, reduced the number of new problems created by land development (even though many old ones remain). Storms and floods since the June 1998 flood have largely eliminated both skepticism around the importance of culvert and bridge design, and the under-sized culverts themselves.

Municipal staff were very clear about one area where management has gone backwards: The ***most recent culvert and bridge inventory prepared by CVRPC for the Valley is not accurate in those towns where a dedicated local staff person did not accompany the CVRPC team for the inventory. In those towns, and the lack of accuracy is hampering prioritization, planning and maintenance.*** In Duxbury, Warren and Waitsfield, there are problems with the inventory and ***a thorough and accurate update is needed immediately*** to support sound maintenance, budgeting, and planning. One individual described the inventory as "worse than nothing, because we are wasting time looking at culverts labeled 'poor condition' that are fine." Another stated that he continues to use the first inventory, and has stopped referring to the more recent one. However, in both of these cases, CVRPC was not accompanied by a town staff person. Updating and enhancing the inventory – with a town staff person along for the inventory to ensure accuracy - is a very important recommendation from this phase of the project.

3.4.3 Capital Project Planning

Planning for capital projects is a very challenging area for municipal staff at the present time, even under the best circumstances, and is an area of great concern for the upcoming Municipal Roads General Permit. Uncertainty around construction season lengths and conditions, the political process around appropriation of funds, and the continued impacts of severe storms and floods which interrupt regular maintenance and put crews into emergency mode, have made capital planning a challenge. With respect to the upcoming permit, one staff person noted that in the world of local road management, adhering to a five-year plan for upgrading specific roads is probably impossible: "We are lucky if our plan at the beginning of the construction season can be executed, a two year plan is about as far out as we can reasonably predict, and with storms, we have no idea what condition a road will be in five years from now." Staff resources to complete capital projects are limited, and hiring outside contractors requires political support and resources for funding, bidding, and construction supervision.

In terms of prioritizing projects, staff recommended focusing on scoping for bridges and culverts—such as the Inferno Road culvert near Sugarbush, the West Hill Road bridge in Warren, and the multi-plate culverts in Duxbury—that are known to need renovation or replacement, and that will require engineering studies and outside contractors to complete. A suggestion from Duxbury in response to the question "If money fell out of the sky, what would you do?" was to identify and hire outside contractors to complete preventive projects (e.g. adding gravel, re-grading and replacing culverts) at known problem sites that could fail in a severe storm. The need to replace plastic culverts installed after TS Irene also was identified as a good project candidate if funding were available.

Overall, however, Valley municipal staff and staff at Sugarbush Resort all stressed the importance of on-going maintenance, condition assessment, and storm preparation as the most important investments that can be made at this time.

3.4.4 Program Administration

There is a great deal of divergence among Valley towns with respect to the amount of staff time, amount of information, and cost accounting being done on roadways in general, and water quality issues in particular. In some cases, budgeting, policies and prioritization are informal; Warren, as with maintenance, has invested more in staff time and resources for budgeting and planning software. The Town is using RMS11, a commercial software program popular in other parts of New England, to assess costs, plan projects, and provide greater justification for scheduling and costs.

Throughout the interview process, participants stressed their concerns about the potential impact on staff resources of the impending Municipal Roads General permit. In the project team's experience, the current level of information and staff concern is very similar to the experience in Chittenden County in 2001 when the MS4 general permit was imposed. In that case, there were concerns about the time horizon for developing plans and achieving compliance, staff time and resources, and where and how resources could be shared among municipalities – all of which were dealt with through a co-permittees meeting group that provided a single point of contact for information, enabled information sharing, and provided the opportunity for meeting two permit criteria (public education and public outreach) through a cooperative project.

Because the Valley towns have many strong initiatives in place already on roadway planning and maintenance (whether formal or informal), there is great opportunity for information sharing of this nature on the roadway permit. A joint, Valley-wide working group among road crew and town staff members for sharing information about the permit process and compliance strategies may be a helpful way to address the information needs, and share best practices. Ideally this would start soon and be done cooperatively with the State's permit manager (Jim Ryan of the Vermont Department of Conservation's Stormwater Program), so that the Valley towns can have input on the content and timing of permit requirements, particularly the requirements for submitting plans and scheduling capital improvements.

3.5 Agriculture

The big picture of agricultural evolution in the Mad River Valley is, on balance, relatively good news for water quality. In the last 1-2 decades, agriculture in the valley has been diversifying and evolving away from dairy. Consolidation of the remaining dairy operations has somewhat lessened the impact of heavy farm trucks (e.g., daily milk truck runs) on local roads. Many farms (examples include Neill Farm, Gaylord Farm) have transitioned to growing livestock for meat – which, in some cases, means fewer animals on the land in the winter, when pastures are least able to support intensive grazing. Livestock operations generally are growing more hay and pasture, and fewer acres of annual row crops like corn—more so on sloping fields off the valley floor. Many of the vegetable growers with land close to the Mad River (examples include Gaylord Farm, Kingsbury Market Garden) grow using practices that minimize the time bare soil is exposed (cover cropping, mulches, etc.). In interviews with farmers, widespread recognition was expressed of the importance of continuous cover (and cover cropping) in keeping soil on the land.

3.5.1 Policy and Regulation: Required Agricultural Practices, Still a Moving Target

Much of the discussion from our January 5, 2016 memo related to the Agency of Agriculture, Food, and Markets' proposed draft Required Agricultural Practices (RAPs) still applies.

Most recently, the Agency of Agriculture, Food, and Markets has released a second draft of the RAPs for public comment (in a press release dated February 23, 2016 (see http://agriculture.vermont.gov/water-quality/regulations/rap). The press release stated that in March, the Agency intended to begin formal rulemaking to meet deadlines associated with Act 64, Vermont's Clean Water Act. The public will again have the opportunity to attend public hearings and provide written comment on the RAPs during the formal public hearing and comment period, and the Agency continues to encourage public feedback and engage with stakeholders prior to the formal comment period. As of April 1, the draft RAPs have not begun the formal rule-making process (they are not posted at https://secure.vermont.gov/SOS/rules/index.php).

During presentations from AAFM at the public hearings, it appeared that under this framework, towns may have some authority to manage more than farm structures (meaning manure management, etc.) at very small agricultural operations through local zoning—though the extent of that authority nor any Towns' interest in taking up that responsibility were not clear. For the MRV towns, where the subject came up during interviews, it was clear that ZAs are not interested in taking on additional regulatory or enforcement responsibility with regard to agricultural activities in the Valley.

The second draft of the RAPs provides some clarity about activities expected to be managed by local towns and municipalities. The current draft indicates that the Agency will require municipalities to take on agricultural activities occurring on parcels smaller than 4 acres in size and managing at least:

a) four equines b) five cattle, cows, or American bison; c) 15 swine; d) 15 goats; e) 15 sheep; f) 15 cervids; g) 50 turkeys; h) 50 geese; i) 100 laying hens; j) 250 broilers, pheasant, Chukar partridge, or Coturnix quail; k) three camelids; l) four ratites; m) 30 rabbits; n) 100 ducks; o) 1,000 pounds of cultured trout; or p) other livestock types, combinations, and numbers as designated by the Secretary.

A farm can demonstrate they are a farm that should be regulated under the RAPs by income or a prospective business plan.

3.5.2 Areas of Challenge for Agriculture and Water Quality

Farmyards and farm roads– Areas where animals congregate, and farm roads often traversed by heavy equipment, were acknowledged in interviews as areas of concern and challenge for farmers in the MRV. Multiple interviewees mentioned that they were making changes that kept barnyards cleaner, and that they were becoming more conscious of runoff and implementing practices that divert water from paths, roads, cow paths, etc. to where it can soak in. One interviewee mentioned adding stone to farm roads and driveways that were previously “a muddy mess” as a practice that reduced both erosion and time devoted to maintenance.

Drainage and ditches – Agricultural drainage, especially farm ditches cutting through stream buffers, is a prominent Taskforce concern. However, agricultural ditches and their maintenance were not commonly mentioned in interviews, either as a water quality issue or maintenance challenge. Conflicts between agricultural drainage and gravel road networks were briefly mentioned (e.g., “road dirt clogging up my ditches”). Several substantial discussions centered on what farmers see as issues of concern along gravel roads. A farmer in Moretown, for instance, noted that he sees investment in sand and gravel rather than adequate stabilization (hay/mulch and seed), to the detriment of the ditching and other maintenance work being completed. “Whatever keeps material and gravel in place, also saves tax dollars and helps water quality.”

Buffers – Where, and how much buffer is enough? What to grow in the buffers? In interviews, it was not disputed that some buffers are necessary and beneficial. The proposed draft Required Agricultural Practices requirements for buffers (and livestock exclusion) everywhere, including for ephemeral streams, are a cause for major concern. Suggestions from interviewees about what to plant in buffers based on their past experience and successes included deep rooted brush, willow (and especially basket willow)—but not large trees unless they have taproots (like elms).

Required Agricultural Practices – The proposed draft RAPs remain a cause of great concern and challenge, even for farmers who anticipate that their operations will require little change in order to comply. The most frequently discussed themes included:

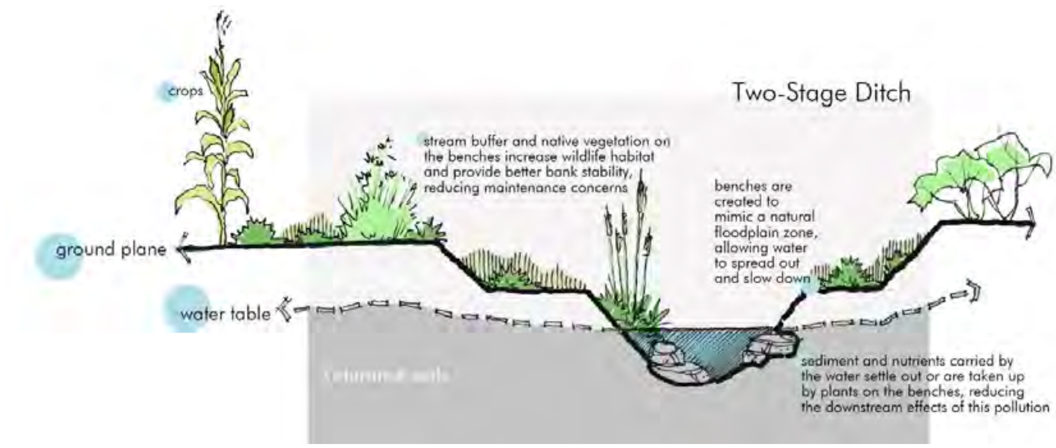
- *Definition of “small farm”* – The very small gross revenue threshold ($2,000 annual), small livestock thresholds (for example, four horses, five cows, 100 chickens), and small acreage thresholds (4+ acres) for requirement to certify

- *Manure management requirements* – New requirements for storing dry stacked manure in one location for no more than 180 days, and not in the same place more than once every 4 years, may be exceedingly tough for small farms (and especially for sloping hill farms with limited suitable areas for dry stacking). More than one farmer interviewed expressed concern that there is no vision in the current draft for practices like grass farming and organic dairy, where animals are required to be on pasture most of the year.
- *Record-keeping, reporting, and inspections* – The requirement for an approved nutrient management plan was commonly seen as "one-size-fits-few"; concerns were also expressed about AAFM resources to conduct inspections (and that the inspectors may spread disease between small operations).
- *Cover cropping* – Crop land subject to flooding would be required to be planted to cover crops before September 15 - which is generally problematic for vegetable farmers, and in years (like 2015, with its late start and warm, long fall) where corn harvest is delayed. Interviewees commonly questioned why cover cropping was not similarly required on upland, sloping fields. "Floodplains don't always flood, but it rains all the time, regardless of landscape position."

3.5.3 Potential Options and Innovations for Agricultural Runoff

Two-stage ditches

Constructed channels in agricultural settings provide important drainage and flood control functions. However, these agricultural channels are often constructed as traditional, trapezoidal ditches, which can require frequent and expensive maintenance do not consider natural ecological functions in their design. An alternative, called a two-stage channel, has proven successful in several Midwestern states over the last decade. The two-stage channel design incorporates benches that function as flood plains and attempts to restore or create some natural alluvial channel processes (NRCS 2007). Although this practice is applied primarily to constructed ditches, it may also have application in natural streams that have undergone incision or in streams where boundary constraints restrict restoration designs, such as in urban or developed areas (NRCS 2007). The two-stage channel design approach is applicable to low gradient ditches and channels that are not undergoing incision (NRCS 2007), so it is likely most appropriate for ditches on the Valley floor.



Cross section illustration of a two-stage ditch. acountrychap.files.wordpress.com/2015/08/two-stage-ditch-enlargement.jpg

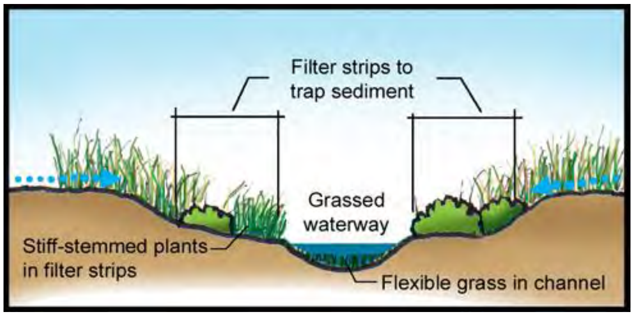
Grassed waterways and vegetated swales

Grassed waterways are shallow vegetated swales designed to convey concentrated runoff to surface waters without causing erosion. They are an accepted conservation practice in Vermont, and can be used to:

- Convey runoff from terraces, diversions, or other water concentrations without causing erosion or flooding
- Reduce gully erosion
- Protect and improve water quality (NRCS-VT, 2011)

Vegetated waterway design requires assessment of several site-specific factors: soil properties, management requirements of the vegetation, and climate (NRCS 2007). Though vegetation establishment is critically important, these practices can be successfully implemented on sloping sites, and thus may be more appropriate on sloping fields off the valley floor. Grassed waterways also depend on good conservation treatment of the contributing watershed and a regular maintenance program. The better the erosion control in the watershed, the less silting there will be in the waterway (NRCS 2007).

Vegetated practices, including filter strips, vegetated swales, and terraces, have been employed with marked success as part of an integrated approach to agriculture at a small number of operations in the Mad River Valley, most notably at Whole Systems Design's Research Farm in Moretown (see, for example, this short video at https://vimeo.com/57208305).



Left: Grassed waterway cross-section schematic (source: http://nac.unl.edu/buffers/guidelines/3_productive_soils/4.html). Right: This photo is from Iowa – but clearly illustrates how grassed waterways can reduce erosion on agricultural hillslopes. The photo was taken in 2013, after major storms dropped 5+ inches of rain in one hour. The grassed waterway at right in the image remained stable, while erosion is apparent on the left-hand side of the image where the slope is similar, but no buffering or grassed waterway was implemented (source: www.nrcs.usda.gov/wps/portal/nrcs/photogallery/ia/soils/gallery/?cid=1733&position=Promo).

Animal trails and walkways

Animal trails and walkways are a well-established conservation practice, consisting of established paths that allow management of animal movement to protect soil and water resources, and ecologically sensitive areas (USDA-NRCS VT 2011).

Trails or walkways should be designed and constructed with consideration of site soil characteristics, and with diversions, water bars, culverts or other structures with stable outlets as necessary to prevent erosion. If culverts, fords, or bridges are needed along the pathway, these should be designed in accordance with the related conservation practice standard for stream crossings (USDA-NRCS-VT 2014).

Animal walkway in Essex County, Vt. Image source: http://www.essexcountynrcd.org/index.php/agricultural-resources

3.6 Forestry

The primary feedback from practitioners related to forestry practices was centered on concerns about the proposed draft AMPs – especially concerns that making certain practices required may create a system that is unintentionally rigid and inflexible. Concerns have also been voiced that (similar to what we've heard from farmers), new requirements will adversely affect the relationship between the industry and the state, making it more adversarial.

A major theme from local officials regarding logging operations (Section 3.3) was that of clearing of wooded lots and "quasi-forestry". In many cases, landowners or contracted foresters are undertaking clearing of wooded lots that "isn't quite forestry," and is not done in the context of a permitted construction project or subdivision. ZAs noted that without the authority for minimal oversight or even notice of these types of activities, erosion-prone sites can be created that affect adjacent properties, streams, and roadway networks. In Duxbury, local officials feel as though they are "stuck" with impacts to water quality, road stability, and increased gravel road maintenance stemming from logging truck traffic traveling to and from Camel's Hump State Forest (and, in other parts of Duxbury outside the MRV, Green Mountain National Forest) lands.

3.6.1 Policy and Regulations

The regulatory landscape for forestry operations in Vermont is continuing to evolve rapidly.

The Department of Forests, Parks, and Recreation (FPR) submitted its "Report and Recommendations on Implementation and Enforcement of Mandatory Acceptable Management Practices for Maintaining Water Quality on Logging Jobs in Vermont" to the Legislature on January 15, 2016. This report contains recommendations for implementing the AMPs as mandatory practices (should the General Assembly choose to do so), changes to enforcement procedures and compliance monitoring that would be needed to administer and enforce the AMPs as required practices. (A separate report addresses whether maple syrup production should be enrolled in the Use Value Appraisal Program (Current Use) as managed forestland.)

Major recommendations in this report for the Legislature's consideration include:

- The existing legal framework applicable to discharges of wastes into state waters from logging is sufficient and should remain unchanged if the AMPs become mandatory.
- If the AMPs become mandatory, only 18 of the 30 AMPs should become bright-line requirements. It may not be feasible to properly implement some AMPs in all situations (e.g., presence of ledge can prevent spacing of waterbars as prescribed). Implementation of the non-mandatory AMPs would still be required to the maximum extent practicable.
- The proposed mandatory AMPs address stream crossing practices during logging, management of surface water runoff on truck roads and skid trails on approaches to stream crossings, and protection and management of forested stream buffers. The recommended mandatory AMPs are:

    - 6.1.4 – Smoothing ruts on skid trails immediately after logging
    - 6.5.1-6.5.8 – Stream crossings on truck roads and skid trails, practices applied during logging (all)
    - 6.6.1, 6.6.2 – Stream crossings on truck roads and skid trails – practices to be applied immediately after logging (all)
    - 6.7.1-6.7.3 – Forest buffers (all)
    - 6.8.1 – Petroleum products and hazardous materials (all)
    - 6.9.1, 6.9.2 – Log landings – practices to be applied during logging
    - 6.10.1 – Log landings – practices to be applied immediately after logging
    - 6.12 (Table 2), 6.13 (Table 3) and 6.14 (Table 4) – tables regarding minimum culvert sizing for temporary stream crossings, methods of seeding and mulching, and minimum forest buffer widths
- A new enforcement procedure is recommended to replace the existing MOU with the DEC Environmental Compliance Division. A compliance monitoring system would be established, and all violations (of both mandatory and non-mandatory AMPs) would be referred to DEC Environmental Compliance Division for enforcement.
- The recommended compliance monitoring system would consist of:
    - A harvest notification system, which would apply to all operations of more than 10,000 board feet or 20 cords annually, requiring notice to FPR and providing information about where and when logging operations will occur;
    - Compliance monitoring of a random sampling of 25% of the harvest notifications received by FPR annually, where a first compliance monitoring inspection by FPR staff would occur during the logging operation, and a second inspection would be conducted after the logging operation was completed.
    - Continued investigation of complaints received related to logging operations.

If the harvest notification and compliance monitoring process described in this report to the Legislature is ultimately approved and implemented, it may have the additional benefit of enabling both ZAs and road foremen in the MRV to have timely information about where logging operations are likely to occur that may impact their road networks—allowing them to plan accordingly, and to coordinate with FPR to offer technical assistance that benefits water quality for the logging operation and the local road network.

As of late March 2016, the current draft of H.857 proposes a program of voluntary notification by landowners of timber harvests, so that state regulators can know more about what logging is actually taking place (http://legislature.vermont.gov/bill/status/2016/H.857).

3.7 Appendix to Section 3: Final interview questions

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Interview and Discussion Questions
Mad River Valley Stormwater Management Project

Birchline Planning LLC and Stone Environmental, Inc. conducted interviews and discussions with Valley stakeholders including municipal officials and staff. This list provides a guide to the questions that were asked as starting points for discussion on Valley water quality issues.

QUESTIONS FOR ROAD COMMISSIONERS/SELECT BOARDS/ADMINISTRATORS

CURB CUT/ACCESS PERMITS

- What issues do you review when a curb cut permit is submitted (e.g. grades, intersection angle, location)?
- What information typically is submitted, and by whom (e.g. engineer, site tech, property owner)?
- What standards would you use – written, informal, common staff knowledge?
- Has a curb cut permit ever been denied? Why?
- Do you ever do site visits before issuing a permit?
- On applications that have to be revised, what types of problems do you typically see (e.g. culvert size, placement, fill material, grading)?
- Do you have an informal maximum width for driveways?

MORETOWN, WARREN: Does the Select Board typically do anything different in review, or ask for different information, than what is reviewed by the road foreman?

ROAD AND DITCH MAINTENANCE ACTIVITIES

- Post-Irene, what changes have you made in terms of road grading, culverts, resurfacing, or other road maintenance and capital improvements? How do you feel that has played out? Are there improvements in runoff, snow removal?
- Are there changes in ditching, culvert sizing, or road maintenance, or specific investments, that you feel can or should be made to reduce runoff? What are impediments to doing those?
- What are your best go-to sources for information or technical help (e.g. Better Backroads, VTrans, other commissioners, etc)?
- How much do you know about the new permit? What do you think the impact will be?

DUXBURY: The Town has been replacing culverts since the April 2014 storm; please tell us about the program. What standards have been used? Is there anything you'd do differently? How have culverts and segments been prioritized? What improvements have you seen since completing it?

PRIVATE ROAD MAINTENANCE

- How much of the driveway and Class IV Town Road system is privately maintained (best guess)? Do you see issues with private maintenance that might affect runoff or water quality?
- What would you say are the differences between great and not-so-great private maintenance approaches?

- Are there actions, trainings, etc. that might help improve private road maintenance with respect to runoff and water quality?

ROAD POLICIES & STANDARDS

- Was your crew involved in writing the Winter Road policy for your town (Warren)? Or, do you think your town should have a winter road maintenance policy?
- What about reclassification? Are there areas where you feel maintenance or conditions would be improved by making roads Class IV Town or taking over maintenance? How well has the policy worked (Duxbury)
- Do you feel it's better to have separate Town standards, or to use VTrans? Do applicants, crews follow standards strictly, or less so? (Note: VTrans B-71, A-76 referenced in different places in Warren, Waitsfield)

WARREN: Please tell us about the 2012 Road Repair plan. Who prepared it? What support or resources did the Town secure to complete it? How has implementation gone? Did standards for ditching, culverts, maintenance change as a result?

QUESTIONS FOR ZONING ADMINISTRATORS/DRB ASSISTANTS/PLANNING COMMISSION AND DRB MEMBERS

ZONING PERMIT REVIEW

- What information do applicants typically provide, and in what format? How often are aerial photos used? Do you refer to aerials or GIS in reviewing applications?
- Since ZP applications ask for information on the "location of streams or wetlands" (or other similar language), how often do applicants provide this? Do you think it's accurate? What might improve the information?
- How often do you do site visits or enforcement? Is construction-phase inspection or enforcement ever done? By whom? What enforcement steps or 'suggestions' might be made (examples welcome).
- When you interact with applicants, how much understanding would you say they have about the potential impact of stormwater runoff?
- **Please tell us about applications within the various flood hazard zones. How well do applicants understand the implications? What types of strategies (i.e. floodproofing, moving structures, etc.) have applicants used? How often are driveways or other infrastructure run through these areas, in your best estimate?
- Policy options:
    - Is it feasible to have applicants submit ZP applications on an aerial base with GIS-mapped resources shown?
    - Would construction-phase checks on land disturbance be possible? How much in the way of time or money would that potentially take?
    - What level of information on erosion control do you think would be useful?

DEVELOPMENT REVIEW

- PUD review: How often is PUD/PRD used?
- How often do applications actually trigger a full plan submittal under the land development regs?
- Who typically prepares the minor vs. major subdivisions that your DRB (or Waitsfield PC) reviews? What additional information does the DRB or PC typically request?

- What does the DRB/PC ask about erosion control in minor subdivisions or applications? Are supplemental resources or technical review ever invoked for minor plans?
- How often are EPSC plans submitted? When submitted, who reviews? Are these ever sent out for technical review? If so, who is your go-to on this?
- Who would you say is the most knowledgeable person on your DRB or PC about water quality issues? What perspective or resources does he/she bring? How much of an effect does that have?
- What written standards (zoning, ANR guidance, other) if any does your DRB or PC refer to?
- How often are applications conditioned with erosion or stormwater-related conditions? What's an example? Can you give us an example of a condition in a written decision? What enforcement or follow up typically occurs?

QUESTIONS FOR FARMERS:

- Post-Irene, did you make any changes to your practices or planning (e.g., changes of crop or grazing placement or rotation, changes to buffers, ditching, or manure management)? If so, how do you feel those have played out?
- Are there changes in practices that you feel can or should be made to reduce erosion or runoff? What are impediments to doing those?
- What kinds of strategies or practices do you use in your operation to maintain or improve the quality of your soils?
- What are your best go-to sources for information or technical help (e.g. AAFM, UVM Extension Service, NOFA-VT, other farmers, etc)?
- Are you familiar with the current Accepted Agricultural Practices from AAFM?
- Are you aware of Act 64 (Vermont's new water quality legislation, signed into law in June 2015)? Are you aware of the recently-proposed changes to the state-issued Required Agricultural Practices? What do you think the impact of these might be on your practices? Your budget?

QUESTIONS FOR FORESTERS:

- Are you familiar with the current Accepted Management Practices (AMPs) from FPR?
- Are you aware of the recently-proposed changes to the AMPs? What do you think the impact of these might be on your practices?
- What are your best go-to sources for information or technical help (e.g. UVM Extension Service, NRCS, other foresters, etc.)?
- Have you participated in LEAP (Logger Education to Advance Professionalism) training program or other types of professional development?
- How do you protect Streamside Management Zones (SMZ) during timber harvesting operations? Have you used portable skidder bridges in your operations?
- Do you see parcelization and forest fragmentation as significant issues for the MRV?

4. TECHNICAL REPORT: ENVIRONMENTAL DATA ASSESSMENT

Our Phase 1 workplan states that:

> The Stone team will complete a GIS-based assessment of physical watershed characteristics, including slopes, soil types, proximity to water resources and the sensitivity of the waterbody, current and planned land use, the location of impervious surfaces including roads, and existing stormwater infrastructure. We will work with the Taskforce to determine the relative weight that should be given to each of these characteristics in order to score and rank different areas within the watershed. Ultimately, this assessment will be used to identify areas within the watershed that may disproportionately contribute to stormwater quality or quantity concerns. The results of this assessment will be presented as a map, or series of maps.

This report provides the methods and results of the environmental data assessments we proposed in our memo dated March 3, 2016.

4.1 Key Findings of the Environmental Data Assessment

There is an abundance of environmental data, of widely varying completeness and quality, in existence for the Mad River Valley. The datasets were developed to serve a variety of purposes and, as such, are not always well-suited for the types of evaluation that have the greatest utility in terms of informing the Ridge to River Program's development. Descriptions of the data sources, as well as methodologies for creating derived datasets where applicable, are included in Section 4.7 as an appendix. Maps of the salient findings are also included in this report. Map 1 includes a numbering convention for all sub-watersheds, which is carried through tables and maps in the remainder of the report. The following findings and points of interest are brought forward from the more detailed discussion so that they are highlighted for Task Force and FMR consideration.

- There is no single impervious cover dataset that is available for the entire Mad River watershed that is both reasonably accurate and relatively up to date, especially in terms of capability to distinguish impervious cover on developed lands from impervious cover associated with the transportation network (Section 4.3.1 and Map 9). Because developed land cover as represented in watershed-wide but low-resolution datasets represents a very small fraction of the overall land cover in the watershed (<5%), the lack of a single, high quality and current impervious cover dataset substantially limits the accuracy of environmental data assessments that seek to associate observed conditions and/or risk with impervious cover. Further, an accurate and current impervious cover dataset is foundational to the ability to track changes in impervious cover over time.
- Although there are active efforts to improve mapping and management of recreational trails in the Valley, currently any assessment would under-estimate the potential influence of recreational trails on water quality (Section 4.4.5). Further, given the more limited extent of the public dataset, it is difficult

to ascertain whether the known trails are indeed representative of trail location throughout the watershed.

- At watershed forest cover thresholds below 65%, work in the Pacific Northwest and elsewhere tends to mark an observed transition in downstream channels from minimally to severely degraded stream conditions (Booth et al. 2002). There are three Mad River sub-watersheds, including Rice Brook and unnamed tributary watersheds 9 and 11, which have less than 65% of their areas in forest cover (Section 4.2.1 and Map 3).
- Overall, road density in the Mad River watershed is slightly higher than the densities observed in watersheds with low development intensity (0.6-1.0 km/km^2) in Chittenden County (Section 4.4.1 and Map 12). Sub-watersheds with the highest road densities are generally those with relatively concentrated development (villages or ski areas), but 30 of the Mad River's 41 catchments (or nearly three-quarters of the sub-watersheds) have over one kilometer of road network per square kilometer of watershed area.
- Private driveways represent 236 km / 147 miles of transportation infrastructure in the Mad River watershed—or half again the length the road network (468 km / 291 miles, Table 9; see also Section 4.4.4 and Map 15). The total length of roads and driveways combined is 704 kilometers or 437 miles. Of the total driveway network, 96 km/60 miles have slopes in excess of 15%, representing about two-fifths of driveways on a watershed basis.
- About one fifth of the Mad River's sub-watersheds host the majority of the Valley's agricultural land cover; Folsom, Freeman, and High Bridge Brooks, as well as five un-named tributaries (7, 8, 9, 11, and 13) close to the Valley floor, have greater than 15% of their total land area in agricultural cover (Section 4.5 and Map 16).
- Roughly 21% (1,436 acres) of the Valley's agricultural land cover was identified as having one or more potential erosion indicators (steep slopes, erodible soils, or both) (Section 4.5.2 and Maps 17-18). Of this, 608 acres are located in close proximity to water resources.
- Much of the Mad River watershed's forested cover may be vulnerable to erosion when disturbed, due to the presence of steep slopes and highly erodible soils. A small portion of the forested land cover (3,708 acres or 4.0% of the Mad River's watershed area) is located in close proximity to water resources (Section 4.6 and Maps 20-21).

4.2 Indicators of watershed health

The datasets catalogued in Section 4.7 were applied to a series of metrics and analyses that may be considered as indicators of overall watershed health. These indicators were tabulated at both at the sub-watershed or tributary scale (where possible and/or where data exist) and across the entire Mad River watershed (Map 1 illustrates the watershed and sub-watershed boundaries).

4.2.1 Watershed Land Cover Indicators

Watershed land cover data available in the 2011 NLCD (Section 4.7.8.1) is shown on Map 2. A brief description of the type of land cover that each classification represents is included below in Table 1. This land cover dataset is summarized by type of cover and by sub-watershed in Table 2.

The Mad River watershed encompasses a total land area of 373 square kilometers (92,122 acres) (Table 2). There are a total of 41 tributary sub-watersheds within the watershed, half of which are named brooks. At the watershed scale, the majority of the land cover as represented in the 2011 NLCD is forest (86%), with lesser areas of shrubland and herbaceous cover (1.4%), planted or cultivated land (7.3%), developed lands (4.3%), barren (0.1%), and open water or wetlands (2.7%) (Table 2).

A key indicator of overall watershed health, and one that is highly relevant for the Mad River watershed, is the **amount of land area in forest cover**. At watershed forest cover thresholds below 65%, work in the Pacific Northwest and elsewhere tends to mark an observed transition in downstream channels from minimally to severely degraded stream conditions (Booth et al. 2002 and references therein). A number of sub-watersheds, including Rice Brook and two un-named tributary watersheds (tributaries 9 and 11, see numbers 16 and 18 on Map 3), have less than 65% of their areas in forest cover (Table 2 and Map 3). Several others, including High Bridge Brook and four un-named tributaries (tributaries 7, 8, 12, and 13, see numbers 10, 14, 20, and 25 on Map 3), are very near or below 75% forest cover—indicating that, depending on other sub-watershed conditions such as effective impervious cover and soil conditions, downstream channels may be subject to degradation. Sub-watersheds with the smallest amounts of forest cover are generally located either near Sugarbush Village (Rice Brook), or in the central portion of the watershed, running from just south of Irasville north to the VT Route 100-100B intersection (Map 3).

Land area and percent of a watershed in impervious cover is another indicator of watershed health that is potentially relevant for the Mad River watershed. In the work noted above, a maximum of 10% watershed effective impervious area similarly tends to mark a transition between minimally and severely degraded stream conditions (Booth et al. 2002 and references therein). Modeling work completed within the Booth et al. 2002 study also suggests that if increases in impervious cover are associated with development policies that allow forest clearing instead of policies that maximize forest retention, watershed effective impervious area thresholds as low as 4% can result in substantial increases in stormwater runoff following development. The 2011 NLCD Percent Developed Imperviousness data for the Mad River watershed (Section 4.7.10.1) indicate that only 520

Table 1. Description of Land Cover Classifications within the National Land Cover Dataset

NLCD Class\ Value	Classification Description
Water	
11	Open Water - areas of open water, generally with less than 25% cover of vegetation or soil.
Developed	
21	Developed, Open Space - areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
22	Developed, Low Intensity - areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.
23	Developed, Medium Intensity - areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
24	Developed High Intensity -highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.
Barren	
31	Barren Land (Rock/Sand/Clay) - areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
Forest	
41	Deciduous Forest - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
42	Evergreen Forest - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.
43	Mixed Forest - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.
Shrubland	
52	Shrub/Scrub - areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
Herbaceous	
71	Grassland/Herbaceous - areas dominated by gramanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
Planted/ Cultivated	
81	Pasture/Hay - areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
82	Cultivated Crops - areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.
Wetlands	
90	Woody Wetlands - areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
95	Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Table 2. Summary of 2011 NLCD by land cover class and sub-watershed area (acres and percentage).

Sub-Watershed Number and Name		Forest (all classes)	%	Shrubland and Herbaceous	%	Planted/ Cultivated	%	Developed (all classes)	%	Developed Impervious (subset of Developed)	%	Barren	%	Open Water and Wetlands	%	Total
1	MR unnamed trib 1	1,139	91	27	2.1	18	1.4	55	4.4	8.4	0.7	2.0	0.2	17	1.3	1,257
2	MR unnamed trib 2	699	84	19	2.3	42	5.1	38	4.6	2.8	0.3	0	0.0	30	3.6	829
3	MR unnamed trib 3	1,390	89	16	1.0	106	6.7	44	2.8	5.9	0.4	2.4	0.2	10	0.7	1,568
4	Welder Brook	2,101	91	10	0.4	35	1.5	112	4.8	11	1.0	0	0.0	62	2.7	2,319
5	Bat Harris Brook	303	93	6.0	1.8	0.7	0.2	6.4	2.0	0.1	0.0	0	0.0	11	3.3	327
6	MR unnamed trib 4	1,572	81	36	1.9	208	10.7	105	5.4	15	0.7	0	0.0	19	1.0	1,940
7	MR unnamed trib 5	2,440	85	16	0.6	307	10.7	99	3.4	8.1	0.3	1.3	0.0	0.0	0.0	2,863
8	MR unnamed trib 6	740	83	16	1.8	86	9.6	26	3.0	3.1	0.4	0	0.0	19	2.2	888
9	Dowsville Brook	5,303	90	139	2.4	181	3.1	243	4.1	22	0.4	0	0.0	26	0.4	5,892
10	MR unnamed trib 7	1,171	71	18	1.1	350	21.3	87	5.3	14	0.9	3.3	0.2	12	0.8	1,642
11	Deer Brook	1,261	100	0	0.0	0	0.0	0	0.0	0.0	0.0	0	0.00	0	0.0	1,261
12	French Brook	1,540	99	2.2	0.1	3.8	0.2	5.3	0.3	0.4	0.0	0	0.0	0	0.0	1,551
13	Shepard Brook	7,518	92	115	1.4	314	3.9	181	2.2	15	0.4	0	0.0	24	0.3	8,152
14	MR unnamed trib 8	2,285	76	40	1.4	476	15.9	136	4.5	31	1.0	1.3	0.0	52	1.7	2,990
15	Pine Brook	2,338	90	9	0.3	220	8.5	34	1.3	1.3	0.1	0	0.0	2.9	0.1	2,604
16	MR unnamed trib 9	751	65	0.0	0.0	325	28.0	78	6.7	11	0.9	0	0.0	5.8	0.5	1,160
17	MR unnamed trib 10	1,556	85	95	5.2	103	5.6	57	3.1	4.6	0.3	0	0.0	12	0.7	1,823
18	MR unnamed trib 11	582	59	15	1.5	274	27.9	99	10.1	25	2.5	0	0.0	10	1.0	981
19	High Bridge Brook	1,564	69	21	0.9	525	23.3	124	5.5	11	0.5	2.9	0.1	14	0.6	2,251
20	MR unnamed trib 12	555	69	15	1.9	106	13.3	105	13.1	41	5.2	1.1	0.1	18	2.3	801
21	Mill Brook	7,233	89	131	1.6	352	4.3	415	5.1	47	0.6	0	0.0	36	0.4	8,166
22	Chase Brook	1,400	82	123	7.2	7.6	0.4	168	9.8	19	1.1	11	0.7	0	0.0	1,710
23	Lockwood Brook	528	84	46	7.3	0.0	0.0	57	9.1	1.8	0.3	0	0.0	0.0	0.0	632
24	Slide Brook	1,598	96	20	1.2	7.3	0.4	19	1.2	1.8	0.1	0	0.0	16	0.9	1,660
25	MR unnamed trib 13	1,579	76	4.0	0.2	351	16.9	122	5.9	22	1.1	0	0.0	22	1.1	2,078
26	Folsom Brook	3,585	79	14	0.3	775	17.2	111	2.5	11	0.2	0	0.0	30	0.7	4,514
27	MR unnamed trib 14	862	78	4.4	0.4	137	12.5	83	7.5	10	0.9	0	0.0	15	1.3	1,102

28	Rice Brook	282	59	24	5.0	17	3.6	139	29.3	28	5.8	12	2.6	1.8	0.4	476
29	Clay Brook	2,545	78	139	4.3	99	3.0	373	11.5	67	2.0	87	2.7	13	0.4	3,255
30	MR unnamed trib 15	1,342	81	2.2	0.1	206	12.5	90	5.4	13	0.8	0	0.0	14	0.9	1,655
31	Bradley Brook	1,473	90	14	0.8	95	5.8	59	3.6	5.2	0.3	0	0.0	0	0.0	1,641
32	Freeman Brook	3,242	78	28	0.7	726	17.4	157	3.8	17	0.4	0	0.0	24	0.6	4,178
33	MR unnamed trib 16	147	85	0.0	0.0	6.9	4.0	20	11.3	4.0	2.3	0	0.0	0	0.0	173
34	MR unnamed trib 17	428	79	11	2.1	35	6.6	64	11.9	10	1.8	0	0.0	0	0.0	539
35	Lincoln Brook	4,691	95	12	0.2	121	2.5	82	1.7	3.2	0.1	0	0.0	12	0.2	4,918
36	MR unnamed trib 18	1,141	87	4	0.3	71	5.4	91	6.9	7.0	0.5	0	0.0	0	0.0	1,307
37	Stetson Brook	3,122	98	26	0.8	0.0	0.0	23	0.7	0.4	0.0	0	0.0	0	0.0	3,171
38	MR unnamed trib 19	497	88	0.0	0.0	0.0	0.0	61	10.8	6.0	1.1	0	0.0	5	0.9	564
39	Mills Brook	753	83	2.9	0.3	26	2.8	42	4.6	1.8	0.2	0	0.0	83	9.1	906
40	Austin Brook	3,095	100	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.3	0.0	3,099
41	MR unnamed trib 20	2,990	93	21	0.7	0.0	0.0	182	5.7	14	0.4	0	0.0	24	0.7	3,217
	Total (sq. meters)	321,079,500	86	5,282,100	1.4	27,168,300	7.3	16,158,600	4.3	2,104,000	0.6	510,300	0.1	2,605,500	0.7	372,804,300
	Total (sq. km)	321.1		5.3		27.2		16.2		2.1		0.5		2.6		372.8
	Total (acres)	79,340		1,305		6,715		3,993		520		126		644		92,122

Note: The NLCD 2011 Percent Developed Impervious Cover dataset is effectively a sub-set of the land cover already included in the Developed land cover classes. Therefore, the Developed Impervious column is not included in calculation of the total land cover or area within each sub-watershed.

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Table 3. Summary of NLCD 2001-2011 land cover change, by land cover class as of 2011 and sub-watershed area (acres and percentage).

Sub-Watershed Number and Name		Forest (all classes)		Shrubland and Herbaceous		Planted/ Cultivated		Developed		Open Water		No Change		Total
		Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	
1	MR unnamed trib 1			5.3	0.4							1,251	99.6	1,257
2	MR unnamed trib 2	19.3	2.3									819	98.8	829
3	MR unnamed trib 3			2.0	0.1							1,568	100.0	1,568
4	Welder Brook											2,319	100.0	2,319
5	Bat Harris Brook	1.1	0.3	1.1	0.3							324	99.3	327
6	MR unnamed trib 4			4.4	0.2							1,934	99.7	1,940
7	MR unnamed trib 5			2.9	0.1							2,860	99.9	2,863
8	MR unnamed trib 6			2.4	0.3							886	99.8	888
9	Dowsville Brook			69	1.2			0.4	0.01	2.9	0.05	5,820	98.8	5,892
10	MR unnamed trib 7							2.2	0.1			1,631	99.4	1,642
11	Deer Brook											1,261	100.0	1,261
12	French Brook			2.2	0.1							1,549	99.9	1,551
13	Shepard Brook	1.8	0.02	38	0.5	7.8	0.1					8,104	99.4	8,152
14	MR unnamed trib 8							0.2	0.0			2,955	98.8	2,990
15	Pine Brook	1.1	0.04									2,602	100.0	2,604
16	MR unnamed trib 9			3.6	0.3							1,160	100.0	1,160
17	MR unnamed trib 10											1,804	98.9	1,823
18	MR unnamed trib 11							0.2	0.0			978	99.8	981
19	High Bridge Brook	1.1	0.05	21	0.9							2,228	99.0	2,251
20	MR unnamed trib 12			8.5	1.1			2.2	0.3	1.3	0.2	794	99.2	801
21	Mill Brook	1.1	0.01	2.2	0.03			2.4	0.03			8,160	99.9	8,166
22	Chase Brook	3.1	0.2	58	3.4			0.9	0.1			1,648	96.4	1,710
23	Lockwood Brook			20	3.2			5.6	0.9			606	96.0	632
24	Slide Brook			17	1.0							1,643	99.0	1,660
25	MR unnamed trib 13											2,075	99.9	2,078
26	Folsom Brook			8.5	0.2							4,506	99.8	4,514
27	MR unnamed trib 14			7.8	0.7							1,099	99.8	1,102
28	Rice Brook			19	4.0			1.3	0.3			456	95.7	476

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29	Clay Brook	2.7	0.1	97	3.0	1.3	0.04	9.3	0.3			3,145	96.6	3,255
30	MR unnamed trib 15											1,655	100.0	1,655
31	Bradley Brook	2.2	0.1	3.6	0.2			6.2	0.4			1,629	99.3	1,641
32	Freeman Brook			24	0.6							4,153	99.4	4,178
33	MR unnamed trib 16	3.6	2.1	3.1	1.8							173	100.0	173
34	MR unnamed trib 17	1.6	0.3	1.3	0.25							535	99.3	539
35	Lincoln Brook	5.3	0.1	10	0.2							4,903	99.7	4,918
36	MR unnamed trib 18			1.6	0.1							1,307	100.0	1,307
37	Stetson Brook											3,171	100.0	3,171
38	MR unnamed trib 19	5.1	0.9	30.9	5.5	7	1.2					521	92.4	564
39	Mills Brook	1.1	0.1	2.9	0.3			3.3	0.4			899	99.2	906
40	Austin Brook											3,099	100.0	3,099
41	MR unnamed trib 20			7.8	0.2							3,209	99.8	3,217
	Total (sq. meters)	203,400	0.1	1,894,500	0.5	64,800	0.02	139,500	0.04	17,100	0.005	370,485,000	99.4	372,804,300
	Total (sq. km)	0.2		1.9		0.1		0.1		0.02		370.5		372.8
	Total (acres)	50		468		16		34		4		91,549		92,122

Note: Only areas where land cover change occurred that was captured in the NLCD 2001-2011 Land Cover Change dataset are summarized in this table. Zero values, where no land cover change was captured for a given land cover and sub-watershed, were removed from the table.

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acres, or 0.6%, of the entire watershed is composed of impervious cover (Table 2). However, the NLCD percent developed imperviousness dataset substantially under-estimates impervious cover in the Mad River watershed, especially for scattered rural development (see Section 4.7.10). This assessment does indicate that Rice Brook and tributary 12 (the land around Waitsfield's historic village and Irasville, number 20 on Map 4) each have greater than 4% impervious land cover (Table 2 and Map 4). This finding is consistent with the historical pattern of development in the Valley, but is not predictive of the potential for stormwater runoff-related impacts from impervious cover located outside the watershed's traditional village or resort development centers. Additional discussion of the impervious cover datasets available for the Mad River watershed, and their quality and applicability, is included in Section 4.3.2.

Changes in land cover between the NLCD 2001 and 2011 datasets were also evaluated and summarized to better understand where in the watershed change is occurring, and particularly where forest cover is being gained, fragmented, or lost in the Mad River watershed in recent years (Table 3 and Map 5). On a watershed scale, less than 1% (about 573 acres) of the watershed area experienced a land cover change that was captured by the NLCD between 2001 and 2011 (Table 3). Changes of land cover to forest, primarily from shrubland or herbaceous cover and thus representing forest succession or regeneration, occurred in about a third of the Mad River's sub-watersheds and represented 0.1% (or about 50 acres) of the watershed area. Notable areas of change to forested land cover were in the Lincoln Brook, Chase Brook, and Tributary 4 and 10 catchments, where new forest areas of 5-20 acres were identified (Table 3 and Map 5). However, the most substantial changes captured by the NLCD 2001-2011 change dataset were changes of forest cover to either the shrubland/herbaceous (0.5% of watershed area, or 468 acres) or developed land cover classes (0.05% of the watershed area, or about 34 acres). Conversion-related land cover changes were identified in over 70% of the Mad River's sub-watersheds. New areas of shrubland/herbaceous cover of 10 acres or more per sub-watershed were identified in the Clay, Chase, Lockwood, Rice, and Slide Brook catchments (ski area development and new ski runs), as well as in Dowsville, Freeman, High Bridge, and Shepard Brooks, and Tributary 8 (scattered rural development, predominantly off the Valley floor) (Table 3 and Map 5).

4.2.2 Biomonitoring Indicators

Macroinvertebrates and fish communities are often affected by changes in the watershed, and by resulting changes in stream flow and water quality, before those watershed changes progress to the point where the stream channel itself becomes unstable. Thus, information about the presence of healthy and thriving fish and "bugs" represents some of the most valuable data available for understanding the health of in-stream ecology. It is important to keep in mind that in-stream biota are affected by the sum of all factors and activities in the watershed, not only those related to stormwater runoff.

4.2.2.1 Macroinvertebrate Assessments

Vermont DEC Watershed Management Division biologists measure the macroinvertebrate populations in running waters as a direct measurement of the aquatic biota which inhabit Vermont' surface waters[12]. By evaluating a series of metrics, the biologists develop assessments that range from poor to excellent, which correspond to a highly degraded to near natural condition respectively. The minimum acceptable condition is "good", which corresponds with the Vermont Water Quality Standards goals for Class B waters. An "excellent" assessment is consistent with Class A1 (ecological waters). All of the streams below 2,500 feet in elevation in the Mad River watershed are classified as Class B, while those above 2,500 feet in elevation are classified as Class A1[13].

Macroinvertebrate monitoring locations, along with the summary result of the most recent macroinvertebrate assessment completed at each location in the Mad River watershed, are shown on Map 6. Data are available for a total of 23 monitoring locations, the majority of which (13 stations) are associated with development at Sugarbush Resort and Mt. Ellen (in the Slide Brook, Rice Brook, Clay Brook, and Bradley Brook watersheds). The most recent macroinvertebrate assessments in the Slide Brook watershed were summarized as "good" to "very good-good"; no assessment has been completed since September 2006. In Rice Brook, the most recent assessments ranged from "good" to "very good". The last macroinvertebrate assessment in Rice Brook was completed in September 2009, two years after the implementation of substantial stormwater BMP retrofits were completed in the watershed as part of the Lincoln Peak base area redevelopment. After the 2009 macroinvertebrate assessment, the stream was removed from the prior to recent substantial development activity in that watershed[14]. In Clay Brook, conditions ranged from "fair-poor" to "fair; the last assessment completed was in September 2015. Biomonitoring locations in this watershed may also be positioned to monitor potential impacts from the resort's wastewater treatment systems, so caution should be used in ascribing potential ecological impacts to stormwater runoff in this catchment. In Bradley Brook, the most recent assessment (completed in September 2006) was summarized as "good-fair".

The remaining macroinvertebrate monitoring stations are located primarily in the Mad River headwaters and along the western watershed slopes in the Shepard Brook and Dowsville Brook watersheds (Map 6). The headwaters sites had macroinvertebrate populations characterized as "very good" to "excellent", and most were assessed in August-September 2015. The single Shepard Brook location was characterized as "good-very good" in 2014. Dowsville Brook headwaters locations were characterized as having "excellent-very good" macroinvertebrate populations in 2009, while at lower elevations in the watershed, the macroinvertebrate populates were characterized as "good" in 2013.

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[12] https://anrweb.vt.gov/DEC/IWIS/Factsheets/Macroinvertebrate.pdf
[13] http://www.watershedmanagement.vt.gov/rulemaking/docs/wrprules/wsmd_wqs2014.pdf#zoom=100
[14] https://www.epa.gov/sites/production/files/2015-10/documents/vt_ricebrook.pdf

4.2.2.2 Fish Assessments

Fish population data provides a measurement of the general health of a lake, pond, or stream's aquatic biota. Since fish occupy the top of the food web, their population integrates the conditions of lower community types. Similar to the macroinvertebrate assessments described above, Vermont DEC Watershed Management Division biologists assess the ecological health of fish populations in running waters as a direct measurement of the ecology of Vermont' surface waters in order to ensure that the state's clean water goals are met[15]. The assessments are summarized to range from "poor" to "excellent", respectively corresponding to a highly degraded or near natural condition. The minimum acceptable condition is "good", which corresponds with the Vermont Water Quality Standards goals for Class B waters. An "excellent" assessment is consistent with Class A1 (ecological waters).

Fish monitoring locations, along with the summary result of the most recent assessment completed at each location in the Mad River watershed, are shown on Map 6. Fish population assessment data are available for a total of four monitoring locations, in the Mad River headwaters and in the Lincoln Brook, Shepard Brook, and Dowsville Brook watersheds (Map 6). All sites had fish populations characterized as "very good" to "excellent", and all were recently assessed (summers of 2014 or 2015).

4.2.3 Water Quality Data and Indicators

Water quality data are available from both Vermont DEC monitoring activities and from the long-standing water quality monitoring program conducted by the Friends of the Mad River (Section 4.7.14). The locations where water quality data have been collected in the Mad River watershed are shown on Map 7.

Water quality data have been collected by Vermont DEC at a total of 64 locations in the Mad River watershed. In many locations, only one or two samples have been collected over time intervals spanning a decade or more, in association with biomonitoring activities. Often, parameters such as conductivity, pH, and temperature were recorded, but other parameters such as turbidity or phosphorus were not measured. It is likely that, with a substantial investment of time and effort, some interesting trends and indicators could be derived from the archive of DEC water quality data. Such an investigation, however, is well beyond the time available to us in developing useful strategies for stormwater management in the Mad River watershed—and it is not certain that even an exhaustive evaluation of these data will result in actionable findings.

Clean, clear water: Where the Friends of the Mad River are collecting water quality data, are the turbidity and total phosphorus results within an acceptable range when compared to the Vermont Water Quality Standards, especially during base flow stream conditions?

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[15] https://anrweb.vt.gov/DEC/IWIS/Factsheets/Fish.pdf

The water quality data gathered the by Friends of the Mad River include consistent sampling locations, an annual monitoring program that includes sampling for total phosphorus (P), turbidity, and *E. coli*, and a dataset spanning a period of over 10 years. Map 7 shows the main-stem and tributary monitoring stations sampled by Friends of the Mad River, and highlights the tributary watersheds draining to sampling points where applicable.

The state of Vermont's Water Quality Standards[16] for total P and turbidity represent indicators of water body, and thus watershed, health. Waters within the Mad River watershed are classified as Class B waters, except at elevations above 2,500 feet NGVD, where waters are classified as Class A1 (ecological waters). All of the Friends' monitoring locations are located in "Class B" portions of the stream network. Relevant water quality criteria for Class B waters, and for which the Friends of the Mad River have collected some water quality data, include:

Turbidity -In Cold Water Fish Habitat waters -None in such amounts or concentrations that would prevent the full support of uses, and not to exceed 10 NTU (nepholometric turbidity units) as an annual average under dry weather base-flow conditions.

Nutrients - compliance with nutrient criteria shall be achieved either by compliance with the nutrient concentration values in Table 5 or by compliance with all nutrient response conditions in Table 5. In situations where the applicable nutrient concentrations are achieved but the nutrient response conditions are not met as a result of nutrient enrichment, the Secretary may establish alternate nutrient concentration criteria on a site-specific basis as necessary to achieve compliance with the nutrient response conditions. All waters shall maintain a level of water quality that provides for the attainment and maintenance of the water quality standards of downstream waters.

The "Table 5" referenced in the paragraph above is included on the following page, as extracted from the Vermont Water Quality Standards.

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[16] http://dec.vermont.gov/sites/dec/files/documents/WSMD_WaterQualityStandards_2014.pdf

Table 5. Nutrient Criteria for Class B Waters Other Than Segments Within Lake Champlain and Lake Memphremagog.

		Small, High-Gradient Streams[1]	Medium, High-Gradient Streams[1]	Warm-Water, Medium-Gradient Streams[1]	Lakes and Reservoirs[2]	All Other Waters
Nutrient Concentrations						
	Total Phosphorus (µg/L)	12[3]	15[3]	27[3]	18[4]	
Nutrient Response Conditions						
	Secchi Disk Depth (meters)				2.6[5]	
	Chlorophyll-a (µg/L)				7.0[4]	
	pH	Not to exceed 8.5 standard units.				
	Turbidity	Consistent with the criteria in Section 3-04 B.1 of these rules.				
	Dissolved Oxygen	Consistent with the criteria in Section 3-04 B.2 of these rules.				
	Aquatic Biota, Wildlife, and Aquatic Habitat	Consistent with the criteria in Section 3-04 B.4 of these rules, implemented according to the numeric thresholds established in the Vermont Department of Environmental Conservation Biocriteria for Fish and Macroinvertebrate Assemblages in Vermont Wadeable Streams and Rivers - Implementation Phase, dated February 10, 2004 or as more recently updated.				

1. Stream type determinations made by the Secretary for application of numerical biological indices in accordance with Section 3-01 D of these rules shall be used for the application of these nutrient criteria.

2. Applies to lakes and reservoirs greater than 20 acres in surface area with a drainage area to surface area ratio less than 500:1, excluding Lake Champlain and Lake Memphremagog.

3. Not to be exceeded at low median monthly flow during June through October in a section of the stream representative of well-mixed flow.

4. June through September mean not to be exceeded in the photosynthetic depth (euphotic) zone at a central location in the lake.

5. June through September mean not to be less at a central location in the lake.

A key criterion in applying the state's water quality criteria for turbidity and total P is that measurements are taken during *baseflow* conditions, equivalent to low median monthly flow during June through October. The FMR water quality data are collected, generally, weekly throughout the monitoring season—and they are collected during all streamflow conditions, including instances where samples are taken at the beginning of a storm event, or shortly after a storm event.

An analysis of water quality data collected by Friends of the Mad River over the years from 2006 – 2015, along with a summary of flow conditions during that time period, was recently completed as part of a larger study of flow and sediment transport in the Winooski River watershed (Underwood 2016). The analysis classified turbidity and total P results based on the date and time the samples were collected, as compared to stream flow conditions and flow categories observed at the USGS stream gage in Moretown. This approach allows for a reasonable screening or "order of magnitude" understanding of which samples were potentially collected during baseflow conditions, and for comparison of those baseflow water quality results to the relevant Vermont Water Quality Standards (Table 4). However, the Moretown gage is near the mouth of the Mad River and responds differently—or not at all—depending on the magnitude of any given rainfall event and the location of the rain event in the watershed. It is possible that localized storms occurred (generating turbidity and associated total P) during sampling in an upstream tributary watershed, which did not register at the Moretown gage at the time of sampling (generally between 6 and 10 AM) (Underwood 2016). For instance, a brief downpour occurring in the Clay Brook watershed during a FMR sampling event could generate runoff and thus an elevated turbidity and/or total P result for that event, while also being a small enough storm to *not* increase the stage or discharge observed at the USGS stream gage in Moretown.

The analysis of the FMR water quality dataset indicates that, during estimated baseflow conditions, both mean turbidity and mean total P concentrations may be elevated in some tributaries relative to the Vermont Water Quality Standards for those parameters (Table 4). This assessment generally indicates that during estimated baseflow conditions over the last decade, mean total P and turbidity concentrations were below the relevant water quality criteria in the main stem of the Mad River (Table 4). In most monitored tributaries, the mean turbidity values observed during estimated baseflow conditions were lower than the water quality standard of 10 NTU. Turbidity concentrations at estimated baseflow were somewhat elevated at stations near major resort development (Bradley, Clay, and Rice Brooks), but were still lower than the water quality criterion. Mean turbidity concentrations in three tributaries (High Bridge, Pine, and Dowsville Brooks) were higher than the 10 NTU water quality criterion during baseflow conditions (Table 4 and Map 7). In contrast, mean total P concentrations measured during baseflow conditions tended to be slightly elevated in the monitored tributaries, and several tributaries' total P concentrations are above the 15 ug/L numeric water quality criterion for medium-size, high-gradient streams (Bradley, Rice, Folsom, High Bridge, Pine, Dowsville, and Welder Brooks) (Table 4 and Map 7).

Table 4. Summary of Turbidity and Total P Data Collected by Friends of the Mad River during Estimated Baseflow Conditions, 2006-2015 (Underwood, 2016)

Site	Description	Stream	Number of Baseflow Samples	Mean Turbidity (NTU)	Mean Total P (ug/L)
1	Warren Falls	Mad River	17	0.55	5.6
9	Punch Bowl	Mad River	1	0.1	2.5
20	Waitsfield Covered Bridge	Mad River	17	0.92	7.3
28	Ward Clapboard Mill	Mad River	17	1.5	8.6
31	Lover's Lane Bridge	Mad River	16	1.7	10.8
2	Bobbin Mill	Lincoln Brook	17	1.2	7.3
4	Warren Store	Freeman Brook	17	3.7	13.1
6	Bridge on West Hill Road	Bradley Brook	17	8.8	18.0
8	Bottom of Sugarbush Access Rd	Clay Brook	17	4.2	10.8
12	Inferno Road Crossing	Clay Brook	17	7.6	15.0
11	Sugarbush Health Club	Rice Brook	17	7.4	21.8
10	Route 100 crossing	Folsom Brook	17	0.95	20.2
18.1	Mill Brook	Mill Brook	16	0.84	5.9
16	German Flats, Rt 17	Chase Brook	17	0.45	6.1
20.1	Joslin Hill Road culvert	High Bridge Brook	17	13.0	26.5
22	North Road Covered Bridge	Pine Brook	17	11.0	21.6
24	Route 100 Bridge	Shepard Brook	17	2.0	9.5
25	Route 100 Bridge	Dowsville Brook	17	10.1	28.6
28.05	Near Stevens Brook Road	Welder Brook	17	3.9	17.7
Note: Mean turbidity and total P values that are equivalent to or above the relevant water quality criterion are highlighted.					

4.3 Indicators of potential impacts from developed lands

The goal of the analyses presented in this and the following sections is to help to discern, at least at a sub-watershed level if not on a finer scale, which types of land use may be contributing disproportionately to stormwater-related impacts—and thus, what kinds of programmatic options may be of the highest priority moving forward.

A series of metrics was proposed to be calculated at the sub-watershed scale to assess how risks to water quality and flood resilience from developed lands, as a separate component from the road network, are distributed across the Valley:

- Total area of developed land—broken down into village center, rural residential, and resort.
- Acres and percentage of watershed impervious cover (see Section 4.2.1)
- Density of developed lands in proximity to water resources
- Existing development in proximity to steep slopes (developed lands on slopes greater than 15%).

Each indicator related to developed lands is presented and discussed below.

4.3.1 Total area of developed land

As of 2011, the National Land Cover Dataset indicated that 3,993 acres, or 4.3% of the watershed area, was classified as "developed" (Table 2). The Taskforce requested that the portion of the watershed classified as "developed land" be further broken down into the types of development typical of the Mad River watershed—village centers, rural residential development, and resort areas (Section 4.7.8.5). In order to calculate this metric, the developed land cover classes were selected from the 2011 NLCD polygon feature class, and combined with zoning districts as re-classified into village center, rural residential, or resort area, as appropriate (see Section 4.7.8.54.7.1) using the geoprocessing "union" function in ArcGIS. The resulting feature class was summarized on the Town, zoning district, land use class, and NLCD developed land use class (gridcode) attributes using the geoprocessing "dissolve" function in ArcGIS.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: NLCD2011_Developed_Zoning_Union_diss

Table 6 below summarizes the developed land use classes in the 2011 NLCD by town, by developed land type specified by the Taskforce, and development intensity as represented in the NLCD. Developed lands as classified by zoning are shown in Map 8.

Table 6. NLCD Developed Land Cover Classes Summarized by Land Use Type

Town	Developed Land Type	NLCD 2011 Developed Land Cover (acres)					All Other	Total
		Open Space	Low Intensity	Medium Intensity	High Intensity	All Developed		
Duxbury	Rural residential	252	41			293	8,996	9,581
Fayston	Resort	37	13	20		70	259	399
	Rural residential	689	34	6.5		730	20,888	22,347
	Village Center			0.15	1.3	1	14	17
Moretown	Rural residential	387	66	6.7		460	10,746	11,666
	Village Center	9.2	11	8.5		28	75	132
Waitsfield	Rural residential	506	170	33	1.3	711	14,940	16,362
	Village Center	44	63	67	9.1	182	243	607
Warren	Resort	44	48	21	6.9	120	134	373
	Rural residential	997	151	38	2.9	1,189	23,417	25,796
	Village Center	35	22	7.4		64	161	289
All Other Towns	Rural residential	124	24	0.01		148	8,252	8,549
Watershed-wide Summary	Resort	81	61	40	6.9	190	393	772
	Rural residential	2,955	486	85	4.2	3,530	87,240	94,301
	Village Center	88	95	83	10	276	493	1,045
TOTALS		3,124	643	208	22	3,996	88,126	96,118

4.3.2 Density of developed lands in proximity to water resources

This metric was initially proposed to be calculated based on the density of impervious cover in proximity to water resources, but the impervious cover datasets available either do not cover the entire watershed, are out of date, or are not of sufficiently high resolution to facilitate this calculation. There is no single impervious cover dataset that is available for the entire Mad River watershed that is both reasonably accurate and relatively up to date (Section 4.7.10), especially in terms of capability to distinguish impervious cover on developed lands from impervious cover associated with the transportation network. The gaps in both of the available datasets are illustrated in Map 9, where, in the area around Sugarbush Village, the impervious cover dataset created by CVRPC for Fayston, Waitsfield, and Warren in 2000 overlays the LCBP impervious cover dataset created in 2013. While the CVRPC impervious cover dataset generally consists of high-quality and accurate coverage, it does not include the Towns of Duxbury or Moretown, and it does not include new impervious created over the last ~15 years. In contrast, the more recent LCBP dataset covers the entire Mad River watershed and captures recent additions of impervious cover with less accuracy—for instance, post-2000 parking lots, driveways, and rooftops, all of which fall into this dataset's "other impervious" classification—but the dataset has very poor coverage of the road network in the Mad River watershed.

An alternate measure, the density of developed lands in proximity to water resources, was calculated instead.

A single feature class was first created to represent water resource proximity. A 50-foot buffer was added to streams with watersheds of less than two square miles in the River Corridors (WaterHydro_RIVERCORRIDORS_clip) feature class as a conservative representation of the state-level River Corridor extent, which is measured on the ground as fifty (50) feet from the top of the stream bank. A 100-foot buffer was added to lakes and ponds greater than 10 acres in size (NHDWaterbody_clip), consistent with the Vermont Shoreland Protection Act[17] (only the Sugarbush snow-making pond and Blueberry Lake fall within this classification). These buffered layers were then combined with the wetlands (Water_VSWI_poly_clip), 100-year floodplains (Emerg_DFIRM_poly_SFHA_clip), and River Corridors (WaterHydro_RIVERCORRIDORS_clip) feature classes using the geoprocessing "union" function in ArcGIS. The resulting feature class was dissolved to create a single water resource proximity layer (WaterResourceProximity_dissolve). The developed land cover classes were selected from the 2011 NLCD, and the resulting layer was unioned with the water resource proximity and sub-watershed boundary feature classes. Finally, the layer was dissolved on the NLCD land cover intensity and sub-watershed name attributes using the geoprocessing "dissolve" function in ArcGIS. Units for the outputs are acres of developed land in proximity to water resources per acre of watershed area.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: WRResourceProximity_NLCD2011Dev_SubWsheds_Union2_diss

The density of NLCD-mapped developed land cover in proximity to water resources in the Mad River watershed ranges from 0 (in the Austin Brook catchment, where no developed land cover is mapped) to 0.052 (in the very small Tributary 19 sub-watershed) (Table 7 and Map 10). The areas of higher developed land cover density in proximity to water resources tend to occur in un-named tributaries close to the VT Route 100-100B corridor along the Valley floor, or in sub-watersheds containing village centers (Map 10). This metric provides some order-of-magnitude estimate of which sub-watersheds may have the most developed land in proximity to water resources. However, the coarse resolution of the NLCD results in under-prediction of the amount of land in rural residential development, and the NLCD developed land cover classes do not effectively distinguish between transportation-related and development-related land covers.

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[17] http://www.watershedmanagement.vt.gov/permits/htm/pm_shoreland.htm

Table 7. Summary of the density of developed lands in proximity to water resources by sub-watershed

Sub-watershed Number and Name		NLCD 2011 Developed Land In Proximity to Water Resources, acres	Watershed area (acres)	Density (acres in proximity to water resources per acre watershed area)
1	MR unnamed trib 1	9.4	1,257	0.007
2	MR unnamed trib 2	4.0	829	0.005
3	MR unnamed trib 3	16.9	1,568	0.011
4	Welder Brook	19.3	2,319	0.008
5	Bat Harris Brook	0.6	327	0.002
6	MR unnamed trib 4	32.3	1,940	0.017
7	MR unnamed trib 5	14.3	2,863	0.005
8	MR unnamed trib 6	11.5	888	0.013
9	Dowsville Brook	23.8	5,892	0.004
10	MR unnamed trib 7	33.9	1,642	0.021
11	Deer Brook	0.2	4,489	0.0001
12	French Brook	0.8	1,551	0.001
13	Shepard Brook	20.9	8,104	0.003
14	MR unnamed trib 8	34.9	2,990	0.012
15	Pine Brook	2.9	2,604	0.001
16	MR unnamed trib 9	12.6	1,160	0.011
17	MR unnamed trib 10	8.0	1,823	0.004
18	MR unnamed trib 11	25.4	981	0.026
19	High Bridge Brook	7.5	2,251	0.003
20	MR unnamed trib 12	18.0	801	0.023
21	Mill Brook	78.8	8,166	0.010
22	Chase Brook	8.5	1,710	0.005
23	Lockwood Brook	0.2	632	0.0004
24	Slide Brook	0.9	1,660	0.001
25	MR unnamed trib 13	27.4	2,078	0.013
26	Folsom Brook	11.2	4,514	0.002
27	MR unnamed trib 14	21.5	1,102	0.020
28	Rice Brook	4.3	476	0.009
29	Clay Brook	10.1	3,255	0.003
30	MR unnamed trib 15	26.3	1,655	0.016
31	Bradley Brook	3.2	1,641	0.002
32	Freeman Brook	14.8	4,178	0.004
33	MR unnamed trib 16	7.8	173	0.045
34	MR unnamed trib 17	14.2	539	0.026
35	Lincoln Brook	13.4	4,918	0.003
36	MR unnamed trib 18	11.8	1,307	0.009

Sub-watershed Number and Name		NLCD 2011 Developed Land In Proximity to Water Resources, acres	Watershed area (acres)	Density (acres in proximity to water resources per acre watershed area)
37	Stetson Brook	10.6	3,171	0.003
38	MR unnamed trib 19	29.2	564	0.052
39	Mills Brook	7.5	906	0.008
40	Austin Brook	0.0	3,099	0.000
41	MR unnamed trib 20	50.4	3,217	0.016
	TOTAL	649	92,122	0.0070

4.3.3 Existing development in proximity to steep slopes

Areas of moderate to steep slopes are vulnerable to erosion, especially during conversion from forested to developed land. Some communities in Vermont and elsewhere have begun restricting development density on such sloping areas, or otherwise restricting the types of development that can take place (U.S. EPA, 2014). In order to explore whether existing development on steep slopes potentially represents an indicator of impacts from developed lands on water quality or erosion hazard, the NLCD developed land cover classes were combined with slope polygons where the percent slope is greater than 15% (dem10_slope_pct_mrv_breaks_Poly) using the "union" geoprocessing function in ArcGIS.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: dem10_slope_pct_Over15_NLCDdev_Union_wshed_diss

Areas where existing developed land cover as represented in the 2011 NLCD is on slopes over 15% are primarily associated with ski area development (both base areas and ski slopes) and with portions of the transportation network (Table 8 and Map 11). The largest acreages of existing development on steep slopes are in the Clay and Rice Brook watersheds, as well as the Mill Brook watershed (Table 8). Several sub-watersheds do not have any NLCD-mapped developed land cover on slopes over 15% (Austin, Bat Harris, Deer, French, Lincoln, Lockwood, Mills, Pine, and Stetson Brooks, as well as one un-named tributary) (Table 8).

Table 8. Summary of Existing Developed Lands on Steep Slopes (>15%).

Sub-watershed Name and Number		Developed Land Cover on Slopes >15%	Watershed area (acres)
1	MR unnamed trib 1	6.5	1,257
2	MR unnamed trib 2	0.3	829
3	MR unnamed trib 3	2.8	1,568
4	Welder Brook	3.0	2,319
5	Bat Harris Brook	0.0	327
6	MR unnamed trib 4	1.7	1,940
7	MR unnamed trib 5	0.6	2,863

Sub-watershed Name and Number		Developed Land Cover on Slopes >15%	Watershed area (acres)
8	MR unnamed trib 6	1.3	888
9	Dowsville Brook	2.4	5,892
10	MR unnamed trib 7	0.1	1,642
11	Deer Brook	0.0	4,489
12	French Brook	0.0	1,551
13	Shepard Brook	3.1	8,104
14	MR unnamed trib 8	5.9	2,990
15	Pine Brook	0.0	2,604
16	MR unnamed trib 9	3.2	1,160
17	MR unnamed trib 10	0.0	1,823
18	MR unnamed trib 11	1.6	981
19	High Bridge Brook	1.7	2,251
20	MR unnamed trib 12	5.2	801
21	Mill Brook	17.3	8,166
22	Chase Brook	7.8	1,710
23	Lockwood Brook	0.0	632
24	Slide Brook	0.2	1,660
25	MR unnamed trib 13	1.4	2,078
26	Folsom Brook	0.7	4,514
27	MR unnamed trib 14	2.3	1,102
28	Rice Brook	21.6	476
29	Clay Brook	56.0	3,255
30	MR unnamed trib 15	2.9	1,655
31	Bradley Brook	1.4	1,641
32	Freeman Brook	1.3	4,178
33	MR unnamed trib 16	3.6	173
34	MR unnamed trib 17	8.4	539
35	Lincoln Brook	0.0	4,918
36	MR unnamed trib 18	3.3	1,307
37	Stetson Brook	0.0	3,171
38	MR unnamed trib 19	3.5	564
39	Mills Brook	0.0	906
40	Austin Brook	0.0	3,099
41	MR unnamed trib 20	4.8	3,217
	TOTAL	175.9	92,122

4.4 Indicators of potential impacts from roads and transportation-related erosion

Several metrics were calculated or attempted at the sub-watershed scale to assess how risks to water quality and flood resilience from road networks are distributed across the Mad River Valley. These indicators were drawn primarily from recent research in the Lake Champlain Basin assessing the impacts of road networks on stream geomorphic condition (Pechenick et al. 2014) and water quality (Wemple et al. 2013, Bartlett 2016).

- Total acres of road network (not possible due to the quality of the impervious cover dataset, see Section 4.7.10).
- Road density (total road length in the sub-watershed divided by sub-watershed area)
- Density of road – stream crossings (number of roads crossing streams per acre or km^2 watershed area)
- % of watershed total impervious area from roads (not possible due to the quality of the impervious cover dataset, see Section 4.7.10).
- Road erosion risk as compared to identified problem areas
- Indicators of erosion risks from private driveways to streams and the road network (driveway-stream crossings and slopes over 15%)
- Potentially metrics for trails – steep slopes, stream crossings

Each indicator related to roads and transportation is presented and discussed below.

4.4.1 Road density

Road density was calculated by summing the lengths of all roadway segments in the E911 roads dataset (which includes mapped Class 4 and private roads, but not trails) and dividing that roadway length by sub-watershed area.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: Emergency_RDS_line_clip_Intersect_wshed

Overall, road density in the Mad River watershed is slightly higher than the densities observed in watersheds with low development intensity (0.6-1.0 km/km^2) in Chittenden County (Bartlett, 2016) (Table 9). Several sub-watersheds, however, have road densities of 2.2 km/km^2 or higher, which in some cases in Chittenden County, were associated with increased nutrient and sediment levels, along with declining habitat quality and geomorphic stability (Table 9 and Map 12). Sub-watersheds with the highest road densities are generally those with relatively concentrated development (village or ski areas), but many of the Mad River's catchments have over one kilometer of road network per square kilometer of watershed area (Map 12).

Table 9. Summary of road density by sub-watershed.

Sub-watershed Name and Number		Road Length (km)	Road Density (km/km^2)	Road Length (mi)	Road Density (mi/mi^2)
1	MR unnamed trib 1	5.3	1.0	3.3	1.7
2	MR unnamed trib 2	5.9	1.8	3.7	2.8
3	MR unnamed trib 3	7.5	1.2	4.7	1.9
4	Welder Brook	11.3	1.2	7.0	1.9
5	Bat Harris Brook	1.6	1.2	1.0	2.0
6	MR unnamed trib 4	16.7	2.1	10.4	3.4
7	MR unnamed trib 5	16.2	1.4	10.1	2.3
8	MR unnamed trib 6	4.2	1.2	2.6	1.9
9	Dowsville Brook	23.3	1.0	14.5	1.6
10	MR unnamed trib 7	9.4	1.4	5.8	2.3
11	Deer Brook	0.1	0.0	0.1	0.0
12	French Brook	2.3	0.4	1.4	0.6
13	Shepard Brook	31.0	0.9	19.3	1.5
14	MR unnamed trib 8	14.9	1.2	9.2	2.0
15	Pine Brook	5.6	0.5	3.5	0.9
16	MR unnamed trib 9	13.5	2.9	8.4	4.6
17	MR unnamed trib 10	7.9	1.1	4.9	1.7
18	MR unnamed trib 11	9.0	2.3	5.6	3.7
19	High Bridge Brook	21.5	2.4	13.4	3.8
20	MR unnamed trib 12	7.2	2.2	4.5	3.6
21	Mill Brook	44.5	1.3	27.6	2.2
22	Chase Brook	7.3	1.1	4.5	1.7
23	Lockwood Brook	3.0	1.2	1.9	1.9
24	Slide Brook	4.9	0.7	3.1	1.2
25	MR unnamed trib 13	8.1	1.0	5.1	1.6
26	Folsom Brook	19.7	1.1	12.2	1.7
27	MR unnamed trib 14	7.8	1.7	4.8	2.8
28	Rice Brook	6.3	3.3	3.9	5.3
29	Clay Brook	28.2	2.1	17.5	3.4
30	MR unnamed trib 15	7.1	1.1	4.4	1.7
31	Bradley Brook	10.7	1.6	6.6	2.6
32	Freeman Brook	31.8	1.9	19.7	3.0
33	MR unnamed trib 16	1.8	2.6	1.1	4.2
34	MR unnamed trib 17	7.4	3.4	4.6	5.5
35	Lincoln Brook	15.0	0.8	9.3	1.2
36	MR unnamed trib 18	6.4	1.2	3.9	1.9
37	Stetson Brook	3.7	0.3	2.3	0.5

Sub-watershed Name and Number		Road Length (km)	Road Density (km/km^2)	Road Length (mi)	Road Density (mi/mi^2)
38	MR unnamed trib 19	2.4	5.1	1.5	8.1
39	Mills Brook	9.3	2.5	5.8	4.1
40	Austin Brook	4.2	0.3	2.6	0.5
41	MR unnamed trib 20	23.6	1.8	14.6	2.9
	TOTAL	467.5	1.3	290.5	2.0

4.4.2 Density of road – stream crossings

Both higher frequency of road-stream crossings and higher road density within 100 meters of a stream have been shown elsewhere in Vermont to be reasonably indicative of the potential for water quality, stream flow, habitat, and stream stability impacts (for example, in Bartlett 2016). Of the two indicators, the frequency of road-stream crossings was the more statistically significant predictor of potential impacts in the Chittenden County watersheds assessed, and so it was chosen for use in this assessment.

In order to calculate this metric, the E911 roads feature class was intersected with the NHDPlus2 Streams feature class in ArcGIS. The total number of intersections was summarized by sub-watershed, and then divided by sub-watershed area.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: Emergency_RDS_NHDFlowline_intersect_wshed

Overall, the density of road-stream crossings of 1.2 crossings/km^2 of watershed area is higher than the densities observed in watersheds with low development intensity (0.5-0.7 crossings/km^2) in Chittenden County (Bartlett, 2016) (Table 10). Several sub-watersheds have road-stream crossing densities well over 1.3 per km^2, which, in some cases in Chittenden County, were also associated with increased nutrient and sediment levels, along with declining habitat quality and geomorphic stability (Table 10 and Map 13). Sub-watersheds with the highest road-stream crossing densities are often those where roads closely parallel streams (Welder Brook and the lower catchments of Mill Brook, for instance) or where roads cut across the upper reaches of many smaller tributaries (Freeman Brook and High Bridge Brook) (Map 13).

Table 10. Summary of Road-and Driveway Stream Crossing Density by Sub-Watershed.

Sub-watershed Name and Number		Road-Stream Crossings			Driveway-Stream Crossings		
		Total Crossings	Crossing Density (#/km^2)	Crossing Density (#/mi^2)	Total Crossings	Crossing Density (#/km^2)	Crossing Density (#/mi^2)
1	MR unnamed trib 1	7	1.4	3.6	3	0.6	1.5
2	MR unnamed trib 2	3	0.9	2.3			
3	MR unnamed trib 3	8	1.3	3.3			
4	Welder Brook	16	1.7	4.4	2	0.6	0.6
5	Bat Harris Brook	2	1.5	3.9	2	1.5	3.9
6	MR unnamed trib 4	10	1.3	3.3			
7	MR unnamed trib 5	16	1.4	3.6	3	0.3	0.7
8	MR unnamed trib 6	6	1.7	4.3	1	0.3	0.7
9	Dowsville Brook	15	0.6	1.6	1	0.0	0.1
10	MR unnamed trib 7	10	1.5	3.9	1	0.2	0.4
11	Deer Brook	1	0.1	0.3			
12	French Brook	3	0.8	2.0	5	1.3	3.4
13	Shepard Brook	33	1.0	2.6	16	0.5	1.3
14	MR unnamed trib 8	15	1.2	3.2	4	0.3	0.9
15	Pine Brook	7	0.7	1.7	4	0.4	1.0
16	MR unnamed trib 9	17	3.6	9.4	4	0.9	2.2
17	MR unnamed trib 10	6	0.8	2.1	2	0.3	0.7
18	MR unnamed trib 11	6	1.5	3.9	2	0.5	1.3
19	High Bridge Brook	24	2.6	6.8	16	1.8	4.5
20	MR unnamed trib 12	5	1.5	4.0	1	0.3	0.8
21	Mill Brook	45	1.4	3.5	17	0.5	1.3
22	Chase Brook	9	1.3	3.4	3	0.4	1.1
23	Lockwood Brook	2	0.8	2.0	1	0.4	1.0
24	Slide Brook	4	0.6	1.5	2	0.3	0.8
25	MR unnamed trib 13	7	0.8	2.2	2	0.2	0.6
26	Folsom Brook	18	1.0	2.6	11	0.6	1.6
27	MR unnamed trib 14	10	2.2	5.8	3	0.7	1.7
28	Rice Brook	2	1.0	2.7			
29	Clay Brook	10	0.8	2.0	4	0.3	0.8
30	MR unnamed trib 15	8	1.2	3.1	2	0.3	0.8
31	Bradley Brook	3	0.5	1.2	1	0.2	0.4
32	Freeman Brook	39	2.3	6.0	14	0.8	2.1
33	MR unnamed trib 16	1	1.4	3.7			
34	MR unnamed trib 17	3	1.4	3.6			
35	Lincoln Brook	23	1.2	3.0	5	0.3	0.7

Sub-watershed Name and Number		Road-Stream Crossings			Driveway-Stream Crossings		
		Total Crossings	Crossing Density (#/km²)	Crossing Density (#/mi²)	Total Crossings	Crossing Density (#/km²)	Crossing Density (#/mi²)
36	MR unnamed trib 18	3	0.6	1.5	1	0.2	0.5
37	Stetson Brook	4	0.3	0.8			
38	MR unnamed trib 19	3	1.3	3.3			
39	Mills Brook	5	1.4	3.5	1	0.3	0.7
40	Austin Brook	6	0.5	1.2			
41	MR unnamed trib 20	19	1.5	3.8			
	TOTAL	434	1.2	3.0	132	0.4	0.9

4.4.3 Road Erosion Risk and Identified Problem Areas

Substantial work has already been completed regarding erosion risks and other impacts of transportation infrastructure on streams in the Mad River watershed. Map 14 includes two important datasets that can be considered either indicators or confirmation of erosion-related impacts.

A state-wide analysis of road erosion risk for Class 3 and 4 roads is available for download from the Vermont ANR Open Data website (http://gis.vtanr.opendata.arcgis.com, search for 'road erosion'). The map shows the results of a state-wide screening assessment analysis of road erosion risk for Class 3 and 4 roads (Section 4.7.12), as the methodology used for the state-wide assessment updated the methods employed during the 2012 *Mad River Valley Erosion Study* to include the results of work performed by UVM researchers in the Mad River and larger Winooski River watersheds quantifying sediment and phosphorus production from the transportation network (Wemple 2013). The map also shows the locations of problem areas identified in the field during the 2011-2012 *Mad River Valley Erosion Study,* confirming that some—but not all—of the areas identified by such screening level tools are representative of conditions on the ground.

4.4.4 Indicators of potential impacts from private driveways

The road-stream crossing density indicator (Section 4.4.2) was also applied to private driveways, to evaluate whether and where the crossings of streams by private driveways may contribute to stormwater- and erosion-related issues in portions of the Mad River watershed.

In order to calculate this metric, the E911 driveways feature class was intersected with the NHDPlus2 Streams feature class in ArcGIS. The total number of intersections was summarized by sub-watershed, and then divided by sub-watershed area.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: Emergency_DW_NHDFlowline_intersect_wshed

The results of this analysis are also included in Table 10 and Map 15. The majority of the 132 located driveway-stream crossings are concentrated in the Deer, Folsom, Freeman, High Bridge, and Mill Brook watersheds (Table 10).

We also investigated the use of a metric to assess erosion-related risks from private driveways to the public road network. Although driveway culverts are privately owned and generally not mapped, we suggest that the presence of driveways located on steep slopes (15% or more) may indicate a risk to the road network from run-on or silting-in of nearby ditches and culverts, especially if the driveway is not well-constructed or well-maintained. To complete this analysis, the E911 driveways layer was combined with slope polygons where the percent slope is greater than 15% (dem10_slope_pct_mrv_breaks_Poly), as well as with sub-watershed boundaries, using the "intersect" geoprocessing function in ArcGIS. The density of steeply sloping driveways (length of driveways divided by sub-watershed area) was also calculated—not as a direct comparison with road density (Section 4.4.1), but in an attempt to better understand the spatial distribution of this potential indicator across the Mad River watershed.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: Emergency_DW_dem10_SlopeOver15_intersect_wshed

Private driveways represent 236 km / 147 miles of transportation infrastructure in the Mad River watershed (Table 11)—or half the length the road network (468 km / 291 miles, Table 9). Of that total driveway network, 96 km/60 miles have slopes in excess of 15%, representing about two-fifths of driveways on a watershed basis. In several catchments it is estimated that there are over 5 kilometers' worth of steeply sloping driveways (Dowsville, Folsom, Freeman, Mill, and Shepard Brooks) (Table 11). In addition, while no single sub-watershed has a catchment-level density of steep driveways greater than 1.0 km steep driveway/km^2 watershed area, a few sub-watersheds do have steep driveway densities of 0.5 km/km^2 or higher (Chase, Freeman, Lockwood, and Rice Brooks, as well as tributaries 10, 11, and 17) (Table 11 and Map 15).

Table 11. Summary of the length and density of driveways with slopes over 15% by sub-watershed.

Sub-Watershed Name and Number		Driveway length with slope >15%		Total Driveway Length		Steep Driveway Density (km driveway >15%/km^2		Percent of Driveways with Slope >15%
		km	mi	km	mi	(km driveway >15%/km^2	(mi driveway >15%/mi^2	
1	MR unnamed trib 1	1.1	0.7	1.8	1.1	0.2	0.4	63
2	MR unnamed trib 2	0.5	0.3	2.2	1.3	0.1	0.2	22
3	MR unnamed trib 3	1.1	0.7	1.5	0.9	0.2	0.3	72
4	Welder Brook	1.7	1.1	4.0	2.5	0.2	0.3	43
5	Bat Harris Brook	0.1	0.1	0.5	0.3	0.1	0.1	18
6	MR unnamed trib 4	1.6	1.0	3.6	2.2	0.2	0.3	46
7	MR unnamed trib 5	2.5	1.6	8.5	5.3	0.2	0.4	30
8	MR unnamed trib 6	1.2	0.7	1.9	1.2	0.3	0.5	60

Sub-Watershed Name and Number		Driveway length with slope >15%		Total Driveway Length		Steep Driveway Density (km driveway >15%/km²		Percent of Driveways with Slope >15%
		km	mi	km	mi	(km driveway >15%/km²	(mi driveway >15%/mi²	
9	Dowsville Brook	5.5	3.4	10.4	6.4	0.2	0.4	53
10	MR unnamed trib 7	2.7	1.7	6.8	4.2	0.4	0.7	40
11	Deer Brook	0.0	0.0	0.0	0.0	0.0	0.0	0
12	French Brook	2.1	1.3	3.3	2.0	0.3	0.5	64
13	Shepard Brook	8.1	5.3	18.3	11.6	0.2	0.4	44
14	MR unnamed trib 8	2.9	1.8	8.2	5.1	0.2	0.4	35
15	Pine Brook	2.1	1.3	6.1	3.8	0.2	0.3	34
16	MR unnamed trib 9	0.9	0.5	6.0	3.7	0.2	0.3	14
17	MR unnamed trib 10	3.7	2.3	9.0	5.6	0.5	0.8	41
18	MR unnamed trib 11	2.0	1.3	6.7	4.2	0.5	0.8	31
19	High Bridge Brook	3.9	2.4	13.4	8.3	0.4	0.7	29
20	MR unnamed trib 12	1.2	0.7	5.5	3.4	0.4	0.6	21
21	Mill Brook	10.9	6.8	23.8	14.8	0.3	0.5	46
22	Chase Brook	3.9	2.4	6.9	4.3	0.6	0.9	57
23	Lockwood Brook	1.3	0.8	2.5	1.6	0.5	0.8	50
24	Slide Brook	1.7	1.1	2.9	1.8	0.3	0.4	59
25	MR unnamed trib 13	0.9	0.6	4.1	2.5	0.1	0.2	23
26	Folsom Brook	5.4	3.4	15.0	9.3	0.3	0.5	36
27	MR unnamed trib 14	1.9	1.2	5.7	3.5	0.4	0.7	34
28	Rice Brook	0.9	0.5	2.0	1.3	0.5	0.7	43
29	Clay Brook	4.3	2.6	9.7	6.0	0.3	0.5	44
30	MR unnamed trib 15	0.2	0.1	2.0	1.3	0.0	0.0	9
31	Bradley Brook	2.9	1.8	5.7	3.5	0.4	0.7	51
32	Freeman Brook	9.0	5.6	20.0	12.4	0.5	0.9	45
33	MR unnamed trib 16	0.3	0.2	0.4	0.2	0.4	0.6	65
34	MR unnamed trib 17	1.5	0.9	3.5	2.2	0.7	1.1	42
35	Lincoln Brook	2.9	1.8	5.4	3.4	0.1	0.2	54
36	MR unnamed trib 18	1.4	0.8	3.8	2.4	0.3	0.4	36
37	Stetson Brook	0.3	0.2	0.3	0.2	0.02	0.03	77
38	MR unnamed trib 19	0.1	0.03	0.1	0.04	0.02	0,04	90
39	Mills Brook	0.4	0.3	2.0	1.2	0.1	0.2	21
40	Austin Brook	0.0	0.0	0.0	0.0	0.0	0.0	0
41	MR unnamed trib 20	0.7	0.4	1.9	1.2	0.1	0.1	36
	TOTAL	96.2	59.8	235.8	146.5	0.3	0.4	41

4.4.5 Recreational trails

Due to the limited nature of the available dataset (see Section 4.7.13), recreational trail assessments were not undertaken. If the Taskforce determines that management strategies around recreational trails are a high priority in the overall management program, additional data collection will be necessary to inform the assessment.

4.5 Indicators of impacts from agricultural activities

Several indicators were calculated at the sub-watershed scale to assess how water quality and erosion-related impacts from agricultural practices may be distributed across the Valley:

- Total acres of land in agricultural use (see Section 4.2.1)
- Acres and percentage of watershed in agricultural use (pasture/hay and cultivated crop production as separate classes, based on the NLCD)
- Proximity of areas in pasture/hayland or cultivated crop production with steep slopes and/or erosive soils to streams
- Areas of pasture/hayland or cultivated crop production with steep slopes (>15%), any soil type
- Areas of pasture/hayland or cultivated crop production with highly erosive soils on any slope, as well as potentially highly erosive soils on slopes of 5% or more
- Density of areas where livestock congregate, especially if close to water (not possible given quality of dataset, see Section 4.7.8.6)

Each indicator related to agricultural lands is presented and discussed below.

4.5.1 Areas of the Watershed in Agricultural Land Cover

The Mad River watershed supports a robust and diverse agricultural community on less than a tenth of the total watershed area. About 7.3% (6,715 acres, or 27.2 km^2) of the watershed is represented in the 2011 NLCD as planted or cultivated land (Table 2). The areas of the watershed in agricultural use are further broken down in the NLCD into land covers of pasture/hay and cultivated crop production.

Polygons in the 2011 NLCD with agricultural land cover were selected from the dataset and combined with the conserved lands (Conserved_Lands_clip, Section 4.7.8.3) and Current Use (Use_Value_Appraisal_Parcels_clip, Section 4.7.8.4) datasets, as well as with sub-watershed boundaries, using the "intersect" geoprocessing function in ArcGIS.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: nlcd2011_mrv_ag_wshed_Intersect_dissolve

A summary of these agricultural land covers by sub-watershed, as well as the amount of land in agricultural use that is mapped as conserved and/or in the Use Value Appraisal Program (Current Use), is provided in Table 12. Roughly 35% (2,367 acres) of the Valley's agricultural land cover is located within a parcel mapped as being enrolled in the Use Value Appraisal Program, while 13% (848 acres) are mapped as being located within conserved parcels or conservation easements (Table 12). Agricultural land cover in cultivated crop production is focused primarily near the Mad River, while hay/pasture land cover tends to be found on the gently to moderately sloping areas off the Valley floor (Map 16). About one-fifth of the Mad River's sub-watersheds host the majority of the Valley's agricultural land cover; Folsom, Freeman, and High Bridge

Brooks, as well as tributaries 7, 8, 9, 11, and 13, all close to the Valley floor, have greater than 15% of their total land area in agricultural cover (Map 16).

There is no readily available GIS dataset that includes information about the locations of farms and farmsteads across the Mad River watershed (Section 4.7.8.6). A dataset was available that includes primarily dairy or livestock farms, but not most of the Valley's smaller or diversified operations, including pastured livestock operations, produce growers, or orchards/vineyards. Updating the farm locations dataset is beyond the scope of this assessment, but at minimum, it could be updated to include the locations of farmers and producers in the Mad River watershed as identified in the Mad River Localvores' 2014 map and farm directory, along with the types of products available from each operation.

Table 12. Summary of agricultural land cover by sub-watershed.

Subwatershed Name and Number		2011 NLCD Agricultural Land Cover (acres)		Agricultural Land Cover in Current Use (acres)	Agricultural Land Cover in Conservation (acres)	Total Agricultural Land Cover (acres)	Percent of Watershed in Agricultural Land Cover
		Pasture / Hay	Cultivated Crops				
1	MR unnamed trib 1	17.6		13.4		17.6	1.4
2	MR unnamed trib 2	37.6	4.9	27.7		42.5	5.1
3	MR unnamed trib 3	94.5	11.1	61.5	1.0	105.6	6.7
4	Welder Brook	28.7	6.0	6.1	2.4	34.7	1.5
5	Bat Harris Brook	0.7				0.7	0.2
6	MR unnamed trib 4	203.3	4.9	124.0		208.1	10.7
7	MR unnamed trib 5	303.1	4.0	189.9	0.1	307.1	10.7
8	MR unnamed trib 6	78.7	6.9	33.1	20.2	85.6	9.6
9	Dowsville Brook	162.1	18.7	60.9	3.2	180.8	3.1
10	MR unnamed trib 7	209.5	140.3	96.2	172.6	349.8	21.3
11	Deer Brook					0.0	0.0
12	French Brook	3.8				3.8	0.2
13	Shepard Brook	292.7	23.8	81.8	56.5	316.5	3.3
14	MR unnamed trib 8	369.4	106.3	92.5	48.8	475.7	15.9
15	Pine Brook	204.8	15.4	137.6		220.2	8.5
16	MR unnamed trib 9	272.9	52.0	25.3	1.3	324.9	28.0
17	MR unnamed trib 10	102.9		45.7		102.9	5.6
18	MR unnamed trib 11	249.5	24.2	75.0	53.1	273.8	27.9
19	High Bridge Brook	524.6		140.7	105.5	524.6	23.3
20	MR unnamed trib 12	96.8	9.6	32.0	20.4	106.3	13.3
21	Mill Brook	344.5	7.3	82.1	29.8	351.8	4.3
22	Chase Brook	7.6		0.9	0.2	7.6	0.4
23	Lockwood Brook					0.0	0.0
24	Slide Brook	7.3				7.3	0.4

Subwatershed Name and Number		2011 NLCD Agricultural Land Cover (acres)		Agricultural Land Cover in Current Use (acres)	Agricultural Land Cover in Conservation (acres)	Total Agricultural Land Cover (acres)	Percent of Watershed in Agricultural Land Cover
		Pasture / Hay	Cultivated Crops				
25	MR unnamed trib 13	299.3	51.8	162.7	110.9	351.1	16.9
26	Folsom Brook	714.8	59.8	380.1	78.4	774.6	17.2
27	MR unnamed trib 14	137.4	0.0	19.0		137.4	12.5
28	Rice Brook	17.1		0.2		17.1	3.6
29	Clay Brook	91.6	7.1	1.2	5.3	98.7	3.0
30	MR unnamed trib 15	183.3	23.1	148.1	0.1	206.4	12.5
31	Bradley Brook	95.4		28.6	6.9	95.4	5.8
32	Freeman Brook	685.6	40.5	255.8	97.3	726.1	17.4
33	MR unnamed trib 16	6.9			5.8	6.9	4.0
34	MR unnamed trib 17	30.0	5.3	1.0		35.4	6.6
35	Lincoln Brook	111.9	9.6	44.0		121.4	2.5
36	MR unnamed trib 18	70.5	0.7		14.4	71.2	5.4
37	Stetson Brook					0.0	0.0
38	MR unnamed trib 19					0.0	0.0
39	Mills Brook	25.8			11.6	25.8	2.8
40	Austin Brook					0.0	0.0
41	MR unnamed trib 20					0.0	0.0
	TOTAL	6,082.3	633.4	2,367.2	848.1	6,715.6	7.3

4.5.2 Potential erosion indicators on agricultural land

The purpose of exploring the indicators below was to evaluate where in the Mad River watershed agricultural land cover, conditions favorable to erosion, and streams and other water resources may intersect. Areas with steep slopes and easily erodible soils are especially vulnerable to erosion following disturbance, which can happen with some frequency on land in agricultural use. These indicators are a sub-set of those used in work completed in the Vermont portion of the Missisquoi Bay watershed in northern Vermont and Quebec, where an extensive monitoring and modeling effort was completed to identify areas of the working landscape that may contribute disproportionate amounts of sediment (and thus phosphorus) to Missisquoi Bay and Lake Champlain—called "critical source areas" in that effort (Stone Environmental, 2011). Some of the assumptions used in this modeling work have also been carried forward into the modeling that is now supporting the Lake Champlain phosphorus TMDL (Tetra Tech, 2015). The steep slope (>15%) and highly erodible soils indicators were chosen for further evaluation because they are both relatively straightforward and because they are easily verifiable in the field.

The following data layers were applied in this assessment:

- Land in agricultural cover: feature class nlcd2011_mrv_ag_wshed_Intersect_dissolve (Section 4.5.1)

- Water resource proximity: feature class WaterResourceProximity_dissolve (Section 4.3.2) was used for consistency with the developed lands assessment.
- Areas of steep slopes: feature class dem10_slope_pct_Over15 (Section 4.3.3) was used for consistency with the developed lands assessment.
- Erodible soils – any soil polygon in feature class Geologic_SO_poly_clip (Section 4.7.7) with attribute HELCLASS = "highly erodible"
    - nlcd2011_mrv_ag_wshed_HighlyErodible

The agricultural land cover feature class was first intersected individually with areas of steep slopes and erodible soils. These two feature classes were then combined using the "union" geoprocessing function in ArcGIS, to better understand where indicators related only to steep slopes, only to highly erodible soils, or to both indicators were distributed across agricultural land cover in the Mad River watershed.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: nlcd2011_mrv_ag_wshed_SteepSlope_Erodible_union

The resulting feature class was then intersected with the water resource proximity feature class to isolate those portions of agricultural land that have steep slopes and/or erodible soils, and that are also close to water resources and thus may have higher potential for erosion to contribute sediment and nutrients to streams.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: nlcd2011_mrv_ag_wshed_SteepSlope_Erodible_WRProx

A summary of agricultural land cover with one or more indicators of potential erosion by sub-watershed, as well as the amount of land cover with these indicators in proximity to water resources, is provided in Table 13. Roughly 21% (1,436 acres) of the Valley's agricultural land cover was identified as having one or more of the potential erosion indicators, representing 1.6% of the total Mad River watershed area (Table 13). Of this, 608 acres (or 0.6% of the Mad River's watershed area) is located in close proximity to water resources (Table 13, Maps 17-18). While Folsom and Freeman Brooks have large acreages in agricultural cover and greater than 15% of their total land area in agricultural cover (Table 12), Mill and Shepard Brooks were mapped as having the greatest acreages in agricultural cover with indicators of potential erosion (Table 13 and Map 17). Sub-watersheds with the highest percentages of mapped erosion indicators as compared to percent sub-watershed agricultural land cover only tended to be highest in watersheds with very limited agricultural land cover, making this a less instructive metric for prioritization (Table 13). However, the total agricultural land cover with potential erosion indicators as a percentage of sub-watershed area may be helpful, indicating that of all the sub-watersheds, Bradley, High Bridge, and Welder Brooks, and seven unnamed tributaries (3, 4, 5, 7, 9, 11, and 16) have more than 3% of sub-watershed area with one or more indicators are flagged (Table 13).

Table 13. Summary of erosion indicators on agricultural land cover (steep slopes and erodible soils) by sub-watershed.

Subwatershed Name and Number		Total Agricultural Land Cover (acres)	Slope >15% (acres)		Highly Erodible Soils (acres)		Slope >15% and Highly Erodible (acres)		Total Agricultural Cover With Indicators		
			Total	In WR Proximity	Total	In WR Proximity	Total	In WR Proximity	Acres	% of ag land cover	% sub-watershed area
1	MR unnamed trib 1	17.6	0.4	0.5	1.9	1.6	0.3	2.1	2.7	15	0.2
2	MR unnamed trib 2	42.5	4.4		3.2		1.6	0.0	9.2	22	1.1
3	MR unnamed trib 3	105.6	2.5	5.7	25.3	13.8	25.5	19.4	53.3	50	3.4
4	Welder Brook	34.7	5.7	1.0	10.4	1.5	7.0	2.6	23.2	67	8.6
5	Bat Harris Brook	0.7			0.2				0.2	37	0.1
6	MR unnamed trib 4	208.1	14.8	3.4	18.2	3.6	27.2	7.0	60.2	29	3.1
7	MR unnamed trib 5	307.1	27.5	2.4	3.6	0.0	5.3	2.5	36.4	12	1.3
8	MR unnamed trib 6	85.6	3.8	3.3	16.1	3.7	16.5	7.1	36.4	42	4.1
9	Dowsville Brook	180.8	15.4	2.2	25.6	2.1	37.5	4.3	78.6	43	1.3
10	MR unnamed trib 7	349.8	15.9	4.8	24.3	8.2	20.2	13.0	60.5	17	3.7
11	Deer Brook	0.0							0.0	49	0.5
12	French Brook	3.8	0.3	0.0	0.1		0.0	0.0	0.3	9	0.0
13	Shepard Brook	316.5	29.4	3.8	36.1	2.8	52.6	6.7	118.1	37	1.5
14	MR unnamed trib 8	475.7	17.5	2.1	32.1	10.1	11.3	12.2	60.9	13	2.0
15	Pine Brook	220.2	9.3	0.4	12.7	0.4	13.2	0.8	35.2	16	1.4
16	MR unnamed trib 9	324.9	11.5	4.4	33.4	9.1	26.3	13.5	71.2	22	6.1
17	MR unnamed trib 10	102.9	8.1	1.0	18.1	2.1	15.8	3.1	42.0	41	2.3
18	MR unnamed trib 11	273.8	15.1	1.7	27.4	9.4	15.3	11.1	57.9	21	5.9
19	High Bridge Brook	524.6	29.0	2.7	30.4	3.9	25.0	6.6	84.4	16	3.8
20	MR unnamed trib 12	106.3	4.1	1.5	6.5	1.4	12.8	2.9	23.4	22	2.9
21	Mill Brook	351.8	67.0	8.4	24.9	8.1	58.0	16.5	149.9	43	1.8
22	Chase Brook	7.6	1.6	0.2	0.0			0.2	1.6	21	0.1
23	Lockwood Brook	0.0						0.0	0.0	0	0.0
24	Slide Brook	7.3	0.0		1.8	0.1	0.1	0.1	1.9	26	0.1
25	MR unnamed trib 13	351.1	6.7	2.1	8.9	0.6	3.6	2.7	19.2	5	0.9
26	Folsom Brook	774.6	28.1	2.8	22.1	2.5	17.8	5.3	68.1	9	1.5
27	MR unnamed trib 14	137.4	6.0	3.0	7.6	0.5	3.4	3.5	16.9	12	1.5
28	Rice Brook	17.1	3.3	0.5	1.8		0.2	0.5	5.3	31	1.1
29	Clay Brook	98.7	10.0	1.6	15.5	2.7	22.4	4.3	47.8	48	1.5
30	MR unnamed trib 15	206.4	11.7	2.4	10.0	0.3	5.0	2.7	26.6	13	1.6
31	Bradley Brook	95.4	13.6	2.1	19.5	2.1	24.8	4.3	58.0	61	3.5
32	Freeman Brook	726.1	32.8	4.3	23.4	7.5	22.0	11.8	78.2	11	1.9
33	MR unnamed trib 16	6.9	0.2		2.5		4.0	0.0	6.8	98	3.9
34	MR unnamed trib 17	35.4	8.0	6.1	1.3	2.3	2.6	8.5	11.9	34	2.2

Subwatershed Name and Number		Total Agricultural Land Cover (acres)	Slope >15% (acres)		Highly Erodible Soils (acres)		Slope >15% and Highly Erodible (acres)		Total Agricultural Cover With Indicators		
			Total	In WR Proximity	Total	In WR Proximity	Total	In WR Proximity	Acres	% of ag land cover	% sub-watershed area
35	Lincoln Brook	121.4	22.3	5.1	16.5	4.8	20.8	9.9	59.5	49	1.2
36	MR unnamed trib 18	71.2	10.2	0.5	6.9	0.4	1.5	0.9	18.6	26	1.4
37	Stetson Brook	0.0						0.0	0.0	0	0.0
38	MR unnamed trib 19	0.0						0.0	0.0	0	0.0
39	Mills Brook	25.8	2.3	0.2	6.2		2.8	0.2	11.2	43	1.2
40	Austin Brook	0.0							0.0	0	0.0
41	MR unnamed trib 20	0.0						0.0	0.0	0	0.0
1	MR unnamed trib 1	17.6	0.4	0.5	1.9	1.6	0.3	2.1	2.7	15	0.2
	TOTAL	6,716	439	80.2	495	106	502	186	1,436	21	1.6

4.6 Indicators of impacts from forestry and logging activities

As with the metrics applied to agricultural land cover in Section 4.5, a few similar, simple metrics and conditions were applied to assess how risks to water quality and flood resilience from logging activities are distributed across the Mad River watershed. These risks are anticipated to be highest in very steeply sloping areas, and in areas with highly erodible soils – especially where these natural conditions occur in proximity to streams or to local roads.

This assessment also illustrates where indicators of potential water quality and resilience impacts occur in the Green Mountain National Forest and Camel's Hump State Forest, on lands that are primarily forested and enrolled in the Use Value Appraisal Program, and on lands where the same conditions occur in forested lands outside these areas. It is possible that where these indicators are mapped outside of National Forest and Current Use lands, a somewhat elevated risk or priority may be considered by the Taskforce, as smaller or more ad-hoc operations where AMPs are less consistently applied may be more likely to impact water quality and local infrastructure. The specific indicators assessed included:

- Forested areas of very steep slopes (>30%), any soil type
- Forested areas with highly erosive soils on slopes of 5% or more
- Forested areas, proximity of steep slopes and/or erosive soils to water resources
- Potentially a metric that highlights areas where local roads are most likely to be impacted by traffic to and from logging sites

Each indicator related to forestry and logging activities is presented and discussed below.

4.6.1 Areas of the Watershed in Forest Cover

The Mad River watershed is, above all, an area of abundant forest cover. At the watershed scale, the majority of the land cover as represented in the 2011 NLCD is forest (79,340 acres, or 86% of the watershed area) (Table 2). The areas of the watershed in forest cover are further broken down in the NLCD into land covers of evergreen, deciduous, and mixed forest.

Polygons in the 2011 NLCD with forest land cover were selected from the dataset and combined with the conserved lands (Conserved_Lands_clip, Section 4.7.8.3) and Current Use (Use_Value_Appraisal_Parcels_clip, Section 4.7.8.4) datasets, as well as with sub-watershed boundaries, using the "intersect" geoprocessing function in ArcGIS.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: nlcd2011_mrv_forest_wshed_Intersect_dissolve

A summary of the forest land covers by sub-watershed, as well as the amount of land in forest cover that is mapped as conserved and/or in the Use Value Appraisal Program (Current Use), is provided in Table 14.

Evergreen forest cover occupies the smallest watershed area of the three forest cover types (10,838 acres or 14%), and tends to be located at the highest elevations in the watershed, as well as in watershed areas with shallow bedrock or shallow groundwater at lower elevations (Map 19). Deciduous forest cover constitutes the largest acreage (47,076 acres or 59%), and primarily occupies the middle watershed elevations, especially on the eastern slopes of the Green Mountains, west of the Mad River (Map 19). Mixed forest cover, including both evergreen and deciduous trees (21,430 acres or 27%), is the remaining forest cover, which is found primarily at lower elevations along streams and on the Valley floor (Map 19).

Substantial portions of the watershed's forest cover are mapped as either being in conservation or in the Use Value Appraisal Program (Map 19). Roughly 42% (33,506 acres) of the Valley's forest land cover is located within a parcel mapped as being enrolled in the Use Value Appraisal Program, while 26% (20,553 acres) are mapped as being located within conserved parcels or conservation easements (Table 14). Of this, 12,810 acres are both conserved and enrolled in the Use Value Appraisal program, leaving 28,873 acres, or 36% of the mapped forest land cover, which is not subject to any legal conservation restriction, or a forestry or land management plan under the UVA program (Table 14).

As discussed in Section 4.2.1, a few sub-watersheds, including Rice Brook and un-named tributary watersheds 9 and 11, have less than 65% of their areas in forest cover (Tables 2 and 14; Maps 3 and 19). Sub-watersheds with the smallest amounts of forest cover are generally located either near Sugarbush Village (Rice Brook), or in the central portion of the watershed, running from just south of Irasville north to the VT Route 100-100B intersection (Maps 3 and 19).

Table 14. Summary of forest land cover by sub-watershed.

Subwatershed Name and Number		2011 NLCD Forest Land Cover (acres)			Forest Land Cover in Current Use (acres)	Forest Land Cover in Conservation (acres)	Forest Land Cover Not in Current Use or Conservation (acres)	Total Forest Land Cover (acres)	Percent of Watershed in Forest Land Cover
		Deciduous	Evergreen	Mixed					
1	MR unnamed trib 1	562	101	475	970		168	1,139	91
2	MR unnamed trib 2	246	107	346	528		171	699	84
3	MR unnamed trib 3	902	56	432	931	18	459	1,390	89
4	Welder Brook	1,307	122	672	953	210	1,147	2,101	91
5	Bat Harris Brook	208	23	73	119	48	174	303	93
6	MR unnamed trib 4	548	269	756	868	17	704	1,572	81
7	MR unnamed trib 5	840	553	1,047	1,565	56	819	2,440	85
8	MR unnamed trib 6	296	91	354	346	100	297	740	83
9	Dowsville Brook	3,827	346	1,130	3,709	595	1,447	5,303	90
10	MR unnamed trib 7	446	219	507	642	82	491	1,171	71
11	Deer Brook	1,096	64	103	1,107	406	21	1,263	100
12	French Brook	1,360	17	163	891	730	150	1,540	99

Subwatershed Name and Number		2011 NLCD Forest Land Cover (acres)			Forest Land Cover in Current Use (acres)	Forest Land Cover in Conservation (acres)	Forest Land Cover Not in Current Use or Conservation (acres)	Total Forest Land Cover (acres)	Percent of Watershed in Forest Land Cover
		Deciduous	Evergreen	Mixed					
13	Shepard Brook	4,948	915	1,658	4,682	980	2,428	7,521	91
14	MR unnamed trib 8	902	519	863	1,555	0	730	2,285	76
15	Pine Brook	1,127	293	918	799	3	1,536	2,338	90
16	MR unnamed trib 9	323	163	266	260	0	491	752	65
17	MR unnamed trib 10	1,012	40	504	847	198	681	1,556	85
18	MR unnamed trib 11	380	70	133	281	272	300	582	59
19	High Bridge Brook	512	535	517	602	175	922	1,564	70
20	MR unnamed trib 12	376	67	112	260	215	218	555	69
21	Mill Brook	4,804	792	1,637	1,721	2,505	3,080	7,233	89
22	Chase Brook	677	516	207	1,060	70	270	1,400	82
23	Lockwood Brook	333	101	95	241	32	255	528	84
24	Slide Brook	879	405	314	758	405	449	1,598	96
25	MR unnamed trib 13	537	376	666	649	625	471	1,579	76
26	Folsom Brook	1,529	809	1,246	1,973	447	1,311	3,584	79
27	MR unnamed trib 14	543	117	202	301	61	534	862	78
28	Rice Brook	233	36	13	4	224	54	282	59
29	Clay Brook	1,418	440	687	778	1,222	904	2,545	78
30	MR unnamed trib 15	489	205	649	565	153	628	1,342	81
31	Bradley Brook	949	147	377	379	254	845	1,473	90
32	Freeman Brook	1,647	645	950	1,236	224	1,960	3,242	78
33	MR unnamed trib 16	126	4	17	109	13	24	147	85
34	MR unnamed trib 17	165	28	235	194	1	234	428	79
35	Lincoln Brook	3,130	659	902	437	2,329	1,939	4,691	95
36	MR unnamed trib 18	634	56	450	196	473	472	1,141	87
37	Stetson Brook	2,417	372	333		2,974	148	3,122	98
38	MR unnamed trib 19	368	19	110		438	59	497	88
39	Mills Brook	316	63	373	70	332	363	753	83
40	Austin Brook	2,629	222	244		2,994	101	3,095	100
41	MR unnamed trib 20	2,037	256	696	919	670	1,417	2,989	93
	TOTAL	47,076	10,838	21,430	33,506	20,553	28,873	79,344	86

4.6.2 Potential erosion indicators on forest land cover

Similar to the screening assessments completed for agricultural land cover, the purpose of exploring the indicators below was to evaluate where in the Mad River watershed forested land cover and conditions favorable to erosion, along with streams and other water resources, may intersect. Areas with steep slopes and easily erodible soils are vulnerable to erosion following disturbance from logging activities, although the correct use of accepted forestry practices can mitigate water quality and erosion-related impacts. These indicators are also a sub-set of those used in the “critical source areas” work described in Section 4.5.2. The slope threshold (>30% as the cutoff for very steep slopes) and highly erodible soils indicators were chosen for further evaluation because they are both relatively straightforward and because they are easily verifiable in the field.

The following data layers were applied in this assessment:

- Land in forest cover: feature class nlcd2011_mrv_forest_wshed_Intersect_dissolve (Section 4.6.1)
- Water resource proximity: feature class WaterResourceProximity_dissolve (Section 4.3.2) was used for consistency with the developed lands and agricultural lands assessments.
- Areas of steep slopes: feature class dem10_slope_pct_Over30 was extracted from the master slope raster dataset (Section 4.7.6).
- Erodible soils – any soil polygon in feature class Geologic_SO_poly_clip (Section 4.7.7) with attribute HELCLASS = “highly erodible” was extracted (Geologic_SO_poly_HighErod).

The forest land cover feature class was first intersected individually with areas of very steep slopes (>30%).

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: nlcd2011_mrv_forest_wshed_SlopeOver30

The forest land cover feature class was next intersected with areas of highly erodible soils. All soils mapped with slopes >30% are classified as “highly erodible”, so to refine the assessment of highly erodible soils, areas with forest cover and slope >30% were excluded.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: nlcd2011_mrv_forest_wshed_HighErod_diss

The resulting feature class was then intersected with the water resource proximity feature class to isolate those portions of forested land cover that have steep slopes and/or erodible soils, and that are also close to water resources and thus may have higher potential for erosion to contribute sediment and nutrients to streams.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: nlcd2011_mrv_forest_wshed_SteepSlope_Erodible_WRProx

A summary of forest land cover with one or more indicators of potential erosion by sub-watershed, as well as the amount of land cover with these indicators in proximity to water resources, is provided in Table 15. Four-fifths of the Valley’s forested land cover (63,439 acres) was identified as having one or more of the potential erosion indicators, representing 69% of the total Mad River watershed area (Table 15). Five sub-watersheds have over 4,000 acres of forested land cover (Deer, Dowsville, Lincoln, Mill, and Shepard Brooks)—and of these, all but Shepard Brook also have more than 4,000 acres of forested cover where one or more indicators of potential impacts related to erosion were identified (Table 15, Maps 20-21, Figure 1).

Though much of the Mad River watershed's forested cover may be vulnerable to erosion when disturbed, of the forested land cover, only 3,708 acres (or 4.0% of the Mad River's watershed area) is located in close proximity to water resources (Table 15, Maps 20-21). Sub-watersheds with the largest acreages of forest cover with indicators in proximity to water resources include Deer, Dowsville, Folsom, Freeman, Lincoln, Mill, and Shepard Brooks, with 160-340 acres of especially vulnerable forested land cover per sub-watershed (Table 15, Figure 1).

Table 15. Summary of erosion indicators on forested land cover (steep slopes and erodible soils) by sub-watershed.

Subwatershed Name and Number		Total Forest Land Cover (acres)	Slope >30% (acres)		Highly Erodible Soils (acres)		Total Forest Cover With Indicators			
			Total	In WR Proximity	Total	In WR Proximity	In WR Proximity	Total	% of forest land cover	% sub-watershed area
1	MR unnamed trib 1	1,139	302	14	765	51	66	1,068	94	85
2	MR unnamed trib 2	699	163	6	385	23	30	547	78	66
3	MR unnamed trib 3	1,390	252	10	970	43	53	1,222	88	78
4	Welder Brook	2,100	406	24	1,431	87	111	1,837	87	79
5	Bat Harris Brook	303	25	1	219	5	6	245	81	75
6	MR unnamed trib 4	1,572	166	13	1,074	60	73	1,240	79	64
7	MR unnamed trib 5	2,440	432	21	1,301	75	96	1,733	71	61
8	MR unnamed trib 6	740	95	5	478	14	20	574	77	65
9	Dowsville Brook	5,303	1,186	63	3,664	182	246	4,850	91	82
10	MR unnamed trib 7	1,171	112	2	729	26	28	841	72	51
11	Deer Brook	4,431	1,406	18	720	55	73	2,126	48	47
12	French Brook	1,540	295	7	1,119	54	61	1,414	92	91
13	Shepard Brook	7,520	1,346	64	4,751	341	405	6,098	81	74
14	MR unnamed trib 8	2,285	304	13	1,507	73	85	1,811	79	61
15	Pine Brook	2,338	603	34	1,117	116	150	1,721	74	66
16	MR unnamed trib 9	752	16	2	378	21	23	394	52	34
17	MR unnamed trib 10	1,556	188	11	1,096	46	57	1,284	83	70
18	MR unnamed trib 11	582	91	6	353	23	28	444	76	45
19	High Bridge Brook	1,564	188	7	706	74	81	895	57	40
20	MR unnamed trib 12	555	176	10	286	8	18	462	83	58
21	Mill Brook	7,233	2,151	95	3,734	238	333	5,885	81	72
22	Chase Brook	1,400	626	23	665	41	64	1,291	92	75
23	Lockwood Brook	528	219	8	223	11	19	442	84	70
24	Slide Brook	1,598	773	9	593	14	23	1,366	85	82

Subwatershed Name and Number		Total Forest Land Cover (acres)	Slope >30% (acres)		Highly Erodible Soils (acres)		Total Forest Cover With Indicators			
			Total	In WR Proximity	Total	In WR Proximity	In WR Proximity	Total	% of forest land cover	% sub-watershed area
25	MR unnamed trib 13	1,579	306	11	875	44	56	1,181	75	57
26	Folsom Brook	3,584	590	34	1,891	223	257	2,481	69	55
27	MR unnamed trib 14	862	256	10	423	18	28	680	79	62
28	Rice Brook	282	112	5	122	11	15	234	83	49
29	Clay Brook	2,545	696	35	596	67	102	1,292	51	40
30	MR unnamed trib 15	1,342	271	7	604	26	33	875	65	53
31	Bradley Brook	1,473	428	14	873	43	57	1,301	88	79
32	Freeman Brook	3,242	668	31	1,381	129	161	2,049	63	49
33	MR unnamed trib 16	147	59	1	86	0.4	2	145	99	84
34	MR unnamed trib 17	428	98	0.1	185	2	2	283	66	53
35	Lincoln Brook	4,691	1,830	82	2,407	175	258	4,237	90	86
36	MR unnamed trib 18	1,141	446	10	496	27	38	943	83	72
37	Stetson Brook	3,122	1,400	77	1,428	96	173	2,828	91	89
38	MR unnamed trib 19	497	232	8.0	168	8	16	400	80	722
39	Mills Brook	753	63	2	263	10	12	326	43	36
40	Austin Brook	3,095	1,476	92	1,343	111	203	2,819	91	91
41	MR unnamed trib 20	2,989	1,195	41	1,294	105	147	2,489	83	77
	TOTAL	79,343	20,737	929	42,702	2,780	3,708	63,439	80	69

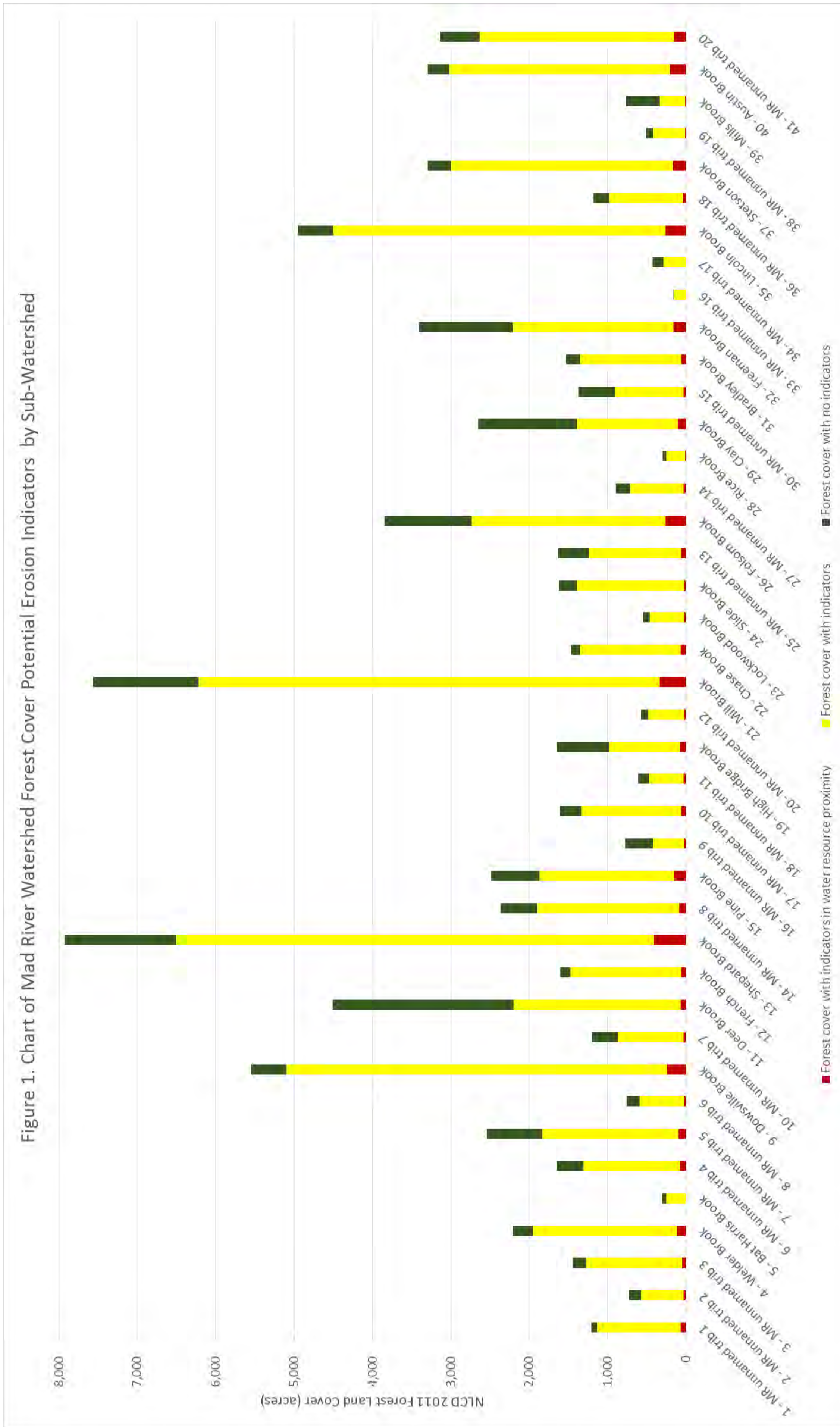

Figure 1. Chart of Mad River Watershed Forest Cover Potential Erosion Indicators by Sub-Watershed

4.6.3 Indicators of impacts on the transportation network from logging activities

We may be able to calculate a metric or spatial analysis that highlights areas where local roads are most likely to be impacted by traffic to and from logging sites. This analysis would combine identification of areas of steep slopes and erosive soils in forest cover with road segments identified as being at high risk for erosion by either the 2012 *Mad River Valley Erosion Study* or the state-wide road erosion risk rankings GIS dataset. This assessment could be completed as part of Task 2, if the Taskforce determines that management strategies around roads to and from logging activities are a high priority in the overall management program.

4.7 Data sources and data development methods

Data sources included in the environmental data assessment, and processing steps used to prepare these datasets for use in assessment, are included below.

4.7.1 Watershed Boundaries

Catchment (or sub-watershed) areas within the Mad River watershed were created from the NHDPlus2 dataset (http://www.horizon-systems.com/nhdplus/). NHDPlus is an integrated suite of application-ready geospatial data sets that incorporate many of the best features of the National Hydrography Dataset (NHD), the National Elevation Dataset (NED), and the Watershed Boundary Dataset (WBD). The use of NHDPlus2 catchments is preferred over the watershed boundaries available in the National Hydrography Dataset, as a much finer level of detail in sub-watershed definition is possible. Catchments within the Mad River watershed were selected and extracted from the NHDPlus2 data, and minor corrections were applied to ensure that the catchment polygons did not overlap and were continuous across the entire watershed area. The post-processing resulted in a total of 51 catchments or sub-watersheds. The NHDPlus2 dataset does not include stream or watershed names, so these were added to the attributes of each sub-watershed where known (Map 1). Unnamed catchments in this dataset thus represent un-named tributaries to the Mad River.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: NHDPlus2_Wsheds_MadRiver

A single watershed boundary for the Mad River was then created from this small-scale catchment dataset by using the geoprocessing “dissolve” function in ArcGIS. This watershed boundary is used to spatially select and extract many other datasets used in the environmental data assessment, in order to limit data inputs to our area of interest.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: MadRiver_Wshed_NHDPlus2_Diss

4.7.2 Hydrography

Hydrography (the locations of rivers, streams, ponds, and lakes) used in these assessments was also derived from the NHDPlus2 dataset. Waterbodies and flowlines (streams) within the Mad River watershed were extracted from the larger dataset by using the geoprocessing “clip” function in ArcGIS.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Classes: NHDFlowline_clip (streams) and NHDWaterbody_clip (lakes and ponds)

4.7.3 Wetlands

The locations of wetlands in the Mad River watershed were taken directly from the Vermont Center for Geographic Information (VCGI) Vermont Significant Wetlands Inventory dataset (http://vcgi.vermont.gov/opendata, search for WaterWetlands_VSWI). Wetlands within the Mad River watershed were extracted from the larger dataset by using the geoprocessing "clip" function in ArcGIS.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Classes: Water_VSWI_poly_clip and Water_VSWICLASS3_poly_clip

4.7.4 Floodplains (FEMA 100-year inundation)

The locations of areas delineated on FEMA Digital Flood Insurance Rate Maps in the Mad River watershed were taken directly from the Vermont Center for Geographic Information (VCGI) FEMA Digital Flood Insurance Rate Maps dataset (http://vcgi.vermont.gov/opendata, search for EmergencyFlood_DFIRM). Within this download, the Emergency_DFIRM_poly_SFHA dataset contains the locations of DFIRM Floodways and Special Flood Hazard Areas, including zones AE (1-percent annual chance floodplains with elevations), A (1-percent annual chance floodplains without elevations), and AO (1-percent annual chance zone of shallow flooding 1-3 feet). Special Flood Hazard Areas within the Mad River watershed were extracted from the larger dataset by using the geoprocessing "clip" function in ArcGIS.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: Emerg_DFIRM_poly_SFHA_clip

4.7.5 River Corridors and Fluvial Erosion Hazard Areas

Information about river corridors, including Fluvial Erosion Hazard Areas (FEH) where they have been mapped in the Mad River watershed, was extracted from Vermont DEC's Statewide River Corridor (SRC) dataset (http://vcgi.vermont.gov/opendata, search for WaterHydro_RIVERCORRIDORS). The Statewide River Corridor dataset includes rivers and streams with watersheds over two square miles. For small streams, with watersheds less than two square miles, the extent of the River Corridor is measured on the ground as fifty (50) feet from the top of the stream bank (for more information, please see http://floodready.vermont.gov/flood_protection/river_corridors_floodplains/river_corridors). River Corridor areas within the Mad River watershed were extracted from the state-wide layer by using the geoprocessing "clip" function in ArcGIS.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: WaterHydro_RIVERCORRIDORS_clip

NOTE: In some areas the SRC dataset includes corridor extents that are smaller than the DFIRM extents along the Mad River, especially along the mainstem between Waitsfield Village and Moretown Village.

4.7.6 Slopes

Ground surface slope across the Mad River watershed was calculated from the best available Digital Elevation Model (DEM). Unfortunately, the highest resolution DEM that is currently available is the 10-

meter DEM extracted from the USGS National Elevation Dataset. Higher-resolution LiDAR data for the Mad River watershed is not currently available, but is anticipated in the spring of 2016 (see http://vcgi.vermont.gov/lidar). The DEM was clipped to the Mad River watershed boundary, and percent slope was calculated across the watershed based on the 10-meter DEM were extracted from VCGI's statewide slope dataset (http://vcgi.vermont.gov/opendata, search for ElevationSlope_SLOPE10M). Areas with slopes >5%, >15%, and >30% were then extracted from the percent slope raster and converted to a polygon feature class. The slope breaks were chosen based on several critical thresholds:

- >5%: Areas with relatively gentle slope, but which are underlain by easily eroded soils, are vulnerable to erosion if not rapidly stabilized. This factor is especially of concern on working lands that may be frequently disturbed, such as agricultural land in annual row crops (Stone Environmental, 2011).
- >15%:Areas of moderate to steep slopes are vulnerable to erosion, especially during conversion from forested to developed land; some communities (Williston, Vermont for example) have begun restricting development density on such sloping areas or otherwise restricting the types of development that can take place (U.S. EPA, 2014).
- >30%: Slopes over 30% should be protected from development in most cases (U.S. EPA, 2014). Steeply sloping areas are some of the most sensitive to erosion following disturbance of any type, whether from forestry, agricultural use, development, or recreational use.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
  Feature Class: dem10_slope_pct_mrv_breaks_Poly

4.7.7 Soil Characteristics

Soil properties, including soil types and specific soil characteristics including hydrologic soil group and highly erosive soils, were obtained from the NRCS soil survey data for Washington County (http://vcgi.vermont.gov/opendata, search for GeologicSoils_SO). The soil series polygon dataset was clipped to the Mad River watershed boundary by using the geoprocessing "clip" function in ArcGIS.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: Geologic_SO_poly_clip

4.7.8 Land Use

4.7.8.1 Land Cover

Land cover estimates are derived primarily from 2011 National Land Cover Database (NLCD) coverages (http://www.mrlc.gov/nlcd11_data.php). The NLCD Land Cover dataset summarizes land cover at a resolution of 30-meter pixels across the entire United States. The NLCD 2001 to 2011 Land Cover Change dataset contains only those pixels identified as changed between the NLCD 2001 and 2011 edition Land Cover data products across the United States, again at a 30-meter pixel resolution. Finally, the NLCD 2011 Percent Developed Imperviousness dataset includes percent developed imperviousness layer for the conterminous United States for all pixels.

The National Land Cover Dataset (NLCD) includes classifications for hay/pasture and cultivated crops at a resolution of 30-meter pixels. No more detailed break-out is possible with this dataset. NLCD data in the Mad River Valley, generally speaking, substantially under-estimates impervious cover and rural developed lands. A simple comparison with a higher-resolution orthophoto illustrates that the NLCD does a reasonable job of picking up paved roads, village centers, and resort development, an average job with classification of agricultural land vs. forest, and a poor job of picking up and correctly classifying scattered rural residential development.

For agricultural land cover, there is also a national Cropland Data Layer (CDL) (http://www.nass.usda.gov/Research_and_Science/Cropland/SARS1a.php) that reports more detail on agricultural uses and which is updated on an annual basis. It is available at the same 30-meter pixel resolution as the NLCD. While the CDL does cover the entirety of the Mad River watershed, the watershed's relatively small fields and pastures result in substantial mis-classification. For this environmental data assessment, it is preferred to rely on the NLCD for a rough estimate of land in agricultural production.

The NLCD 2011 Land Cover dataset was clipped to the Mad River watershed boundary, and the land cover area within the boundary was summarized by class and sub-watershed.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Classes: nlcd2011_mrv (raster), nlcd2011_mrv_poly (polygon feature class)
- Data Table by subwatershed: tblNLCD2011_BySubWshd (units are square meters). The class values can be found here: http://www.mrlc.gov/nlcd11_leg.php

The NLCD 2001 to 2011 Land Cover Change dataset was clipped to the Mad River watershed boundary, and the land cover area within the boundary was summarized by class and sub-watershed.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: nlcd2011_2001_change_mrv
- Data Table by subwatershed: tblNLCD2011_2001_Change_BySubWshd (units are square meters). The class values are the 'to or 2011' class and there is no record of the 'from or 2001' class (class can be found here: http://www.mrlc.gov/nlcd11_leg.php).

4.7.8.2 Green Mountain National Forest lands

Mapping of Green Mountain National Forest lands within the Mad River watershed was obtained as a sub-set of the Conserved Lands dataset described in Section 1.8.3 below.

4.7.8.3 Conserved lands

The primary data source regarding conserved lands in the Mad River Valley was the Vermont Conserved Lands database (https://www.uvm.edu/rsenr/sal/vtcons.html), as available from VCGI (http://vcgi.vermont.gov/opendata, search forCadastralParcels_CONSPUB). Additional conserved lands datasets were provided by the Central Vermont Regional Planning Commission, and by consultants to the Mad River Valley Planning District. Some of these datasets, such as certain privately owned conserved lands and select properties conserved by the Vermont Land Trust, were provided for use in analyses but cannot be specifically identified or displayed on maps. The conserved lands dataset was clipped to the Mad River watershed boundary by using the geoprocessing "clip" function in ArcGIS.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: Conserved_Lands_clip

4.7.8.4 Land in Use Value Appraisal Program (Current Use)

The state-wide dataset of land areas enrolled in the Use Value Appraisal Program was downloaded from the Vermont ANR Atlas (http://gis.vtanr.opendata.arcgis.com/, available under 'Cadastral and Legal Land Descriptions') and clipped to the Mad River watershed boundary.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: Use_Value_Appraisal_Parcels_clip

4.7.8.5 Rural Residential Development, Village Centers, and Resort Areas

The land area in the Mad River watershed devoted to rural residential development, village centers, and resort areas as sub-sets of developed lands will be estimated based on zoning district GIS data, using the following methodology for each of the five Mad River Valley Towns.

Duxbury:

- "Village center" = All NLCD land use classes within Village district – note, however, that Duxbury's Village District is not within the Mad River watershed.
- "Rural residential" = NLCD developed land use classes (Developed / open space, Developed, low intensity, etc.) within all other zoning districts (predominantly Ecological Reserve, Timber Management and Wildlife, Forest Recreation, Rural Agricultural I and II).

Fayston:

- "Village center" = All NLCD land use classes within Irasville Commercial District.
- "Resorts" = All NLCD land use classes within Resort Development District (identified in the zoning shapefile provided by CVRPC as the "Commercial Recreation District"). Note this does not capture (the majority of) ski runs, those are located in Forest or Soil & Water Conservation Districts and thus are classified in 'rural residential'.
- "Rural residential" = NLCD developed land use classes (Developed / open space, Developed, low intensity, etc.) within all other zoning districts (predominantly Forest, Recreation, Soil & Water Conservation, and Rural Residential districts).

Moretown:

- "Village center" = All NLCD land use classes within Village District.
- "Rural residential" = NLCD developed land use classes (Developed / open space, Developed, low intensity, etc.) within all other zoning districts (predominantly Preserve and Agricultural-Residential).

Waitsfield:

- "Village center" = All NLCD land use classes within Waitsfield Village Business, Waitsfield Village Residential, Irasville Commercial districts. Limited Business and Industrial districts were also included in 'village center' use class for analysis.
- "Rural residential" = NLCD developed land use classes (Developed / open space, Developed, low intensity, etc.) within all other zoning districts (predominantly Agricultural Residential and Forest Reserve districts).

Warren:

- "Village center" = All NLCD land use classes within Warren Village Commercial, Historic Residential Districts. We also included Route 100 Commercial, Bobbin Mill Commercial, German Flats Commercial districts in the 'village center' land use class for analysis.
- "Resorts" = All NLCD land use classes within Sugarbush Commercial District, Sugarbush Residential District. Note this does not capture ski runs, those are in Forest Reserve District. Ski runs are therefore showing up in the "rural residential" class.
- "Rural residential" = NLCD developed land use classes (Developed / open space, Developed, low intensity, etc.) within all other zoning districts (predominantly Rural Residential, Forest Reserve, Vacation Residential).

Zoning district boundaries for each of the five MRV Towns were obtained from CVRPC. The zoning district polygon files were merged into a single feature class and clipped to the Mad River watershed boundary. In order to capture portions of the Mad River watershed that fall outside the five Towns, this feature class was also unioned with the watershed boundary. A text field called "LU_Class" was added to the resulting feature class, containing the designation "Village Center", "Resorts" or "Rural Residential" for each zoning district polygon as described above, to facilitate analysis. A text field containing the town name was also added. Finally, the resulting feature class was dissolved on the town name, zoning district name, and land use class attributes.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: MRV_Zoning_clip_merge_wshedu_diss2

4.7.8.6 Farm Locations

The farm location dataset used in these assessments was created by Stone staff for an earlier project exploring the feasibility of composting and biogas generation operations on a state-wide basis. The locations of currently regulated large and medium-size farm operations were obtained from the State of Vermont. The locations of other, smaller farms are based on E911 locations. Due to the project's focus, this dataset includes primarily dairy or livestock farms, but not most of the Valley's smaller farms. The farm-location E911 points may not be the actual barns or heavy use areas where livestock congregate. The dataset also does not readily capture pastured livestock operations, produce growers, or orchards/vineyards. This dataset has not been checked to determine whether farms in the Mad River Valley have been created or have ceased operation since the dataset was created. Updating the farm locations dataset is beyond the scope of this assessment, but we recommend that, at minimum, the dataset be updated to include the locations of farmers and producers in the Mad River watershed as identified in the Mad River Localvores' 2014 map and farm directory, along with the types of products available from each operation.

This state-wide farm locations dataset was clipped to the Mad River watershed boundary by using the geoprocessing "clip" function in ArcGIS.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: Farms_clip

4.7.9 Existing Stormwater Infrastructure

Several sources of information regarding existing stormwater management infrastructure are available, primarily from Vermont DEC and VCGI. Closed drainage system mapping data is available from VT DEC only in the Moretown and Waitsfield village areas (http://gis.vtanr.opendata.arcgis.com, search for "stormwater infrastructure"). These data are generally developed by Vermont DEC in advance of investigations of the closed drainage networks for "illicit" (non-stormwater) discharges.

A bridge and culvert inventory is available for public road networks (https://www.vtculverts.org/). Data regarding the locations and conditions of culverts in an earlier version of this inventory was used in the completion of the state-wide road erosion risk analysis (Sections 4.7.12 and 4.4.3). Given comments regarding the completeness and accuracy of the latest version of the culvert inventory received during interviews with MRV road foremen, detailed assessment using the culvert inventory as a data source was not undertaken.

4.7.10 Impervious Cover

Several impervious cover datasets, of widely varying completeness and quality, are available for part or all of the Mad River watershed, as described below.

4.7.10.1 NLCD 2011 Percent Developed Imperviousness

This dataset includes percent developed imperviousness layer for the conterminous United States at a resolution of 30-meter pixels (http://www.mrlc.gov/nlcd11_data.php). It includes spatial coverage for the entire watershed, but at a very coarse resolution (see Section 1.8.1).

The NLCD 2011 Percent Developed Impervious dataset was clipped to the Mad River watershed boundary, and the impervious area within the boundary was summarized by sub-watershed. The summary of impervious area from the NLCD dataset is a little confusing because it is calculated based on a percent value, which is stored as an integer. The 'SUM' is the sum of percent impervious, which is stored as an integer. To calculate IMPERVIOUS_AREA, we used the following steps:

5. ([SUM_]/100)*900
6. Each grid cell is 900 square meters, so area is in square meters
7. PCT_IMPERVIOUS: 100 * [IMPERVIOUS_AREA] / [AREA]

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: nlcd2011_impervious_mrv
- Data Table by subwatershed: tblNLCD2011Impervious_BySubWshd

4.7.10.2 Lake Champlain Basin Impervious Surface Mapping

GIS coverage of impervious cover created using 1-meter resolution imagery, and including separate classifications for roads\railroads and other impervious surfaces, is available from the Lake Champlain Basin Program as described in *Mapping Impervious Surfaces in the Lake Champlain Basin* (2013). It can also be downloaded from VCGI (http://vcgi.vermont.gov/opendata, search for LandLandcov_IMPERVLCB2011). This dataset is somewhat more accurate in depicting the locations of certain types of impervious cover—for instance, parking lots, driveways, and rooftops, all of which fall into this dataset's "other impervious" classification. In the Mad River watershed, in some cases, roads are mis-classified as “other impervious”. This impervious cover dataset has **very poor** coverage of the road network in the Mad River watershed.

The Lake Champlain-Basin-wide impervious surface dataset was clipped to the Mad River watershed boundary by using the geoprocessing “clip” function in ArcGIS.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: Land_IMPERVLCB2011_poly_clip

4.7.10.3 CVRPC Impervious Cover Dataset (2000)

An impervious cover dataset produced by CVRPC for Fayston, Waitsfield, and Warren, circa 2000, was provided by Vermont DEC. This dataset classifies impervious cover by type (including roads, parking lots, structures, recreational, clear cut, and unknown). The dataset is generally consists of high-quality and accurate coverage, appearing to be hand-digitized based on orthophotograpy. The dataset contains some relatively minor imperfections, mostly mis-classifications, but it is a good snapshot in time--especially for structures and parking. It provides a much more accurate representation of road network impervious cover compared to the LCBP data, though in some cases it still does not accurately capture driveways. However, this dataset does not include the Towns of Duxbury or Moretown, and it does not include new impervious created over the last ~15 years.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: CVRPC_impervious_2000_poly

4.7.11 Road Network and Driveways (E911 data)

Details regarding the routes of roads, including Class 4 roads, some private roads, and major trails, are available from VCGI (http://vcgi.vermont.gov/opendata, search for EmergencyE911_RDS). This dataset is of excellent quality for computing metrics including road length or density in any given subwatershed, erosion risks due to slope or proximity to a waterbody, etc. However, it contains no information about road width and is thus a poor indicator of impervious surface area related to the road network without further processing that is beyond the scope of this project.

The state-wide road network dataset was clipped to the Mad River watershed boundary by using the geoprocessing “clip” function in ArcGIS. It was assumed that any feature in this dataset classified as a trail was already included in the recreational trails dataset (see Section 1.10.5) and was therefore removed from the roads coverage.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: Emergency_RDS_line_clip

Details regarding the routes of driveways are also available from VCGI (http://vcgi.vermont.gov/opendata, search for EmergencyE911_DW). The E911 Driveways dataset generally contains information regarding the routes of driveways between roads and E911 structure points. It does not cover private roads where there are no E911 addresses to reach, so it will not provide information about private infrastructure such as logging roads. As with the E911 road network data, this dataset is of excellent quality for computing metrics including driveway length or density in any given subwatershed, erosion risks due to slope or proximity to a waterbody, etc. However, it contains no information about driveway width and is thus a poor indicator of impervious surface area related to driveways without further processing that is beyond the scope of this project.

The state-wide driveway dataset was clipped to the Mad River watershed boundary by using the geoprocessing “clip” function in ArcGIS.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: Emergency_DW_line_clip

4.7.12 Road Erosion Risk Datasets

The *Mad River Valley Erosion Study, Final Report* (2012) included a GIS analysis performed by CVRPC on Class 3-4 roads; this was ground-truthed by Watershed Consulting. Priority sites were further assessed and designs were provided for a subset of priority projects—some of which have been implemented. Attachment G from this report included GIS data that were provided to Friends of the Mad River.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Classes: MRVErosion_Master_lines and MRVErosion_Master_points

A state-wide analysis of road erosion risk for Class 3 and 4 roads is available for download from the Vermont ANR Open Data website (http://gis.vtanr.opendata.arcgis.com, search for ‘road erosion’). This screening assessment was completed using similar but not identical methodology for road erosion risk analysis compared to the Mad River watershed-specific assessment described above. The state-wide dataset was completed in 2014, when Stone was contracted by the ANR Ecosystem Restoration Program to conduct the Class 3 and Class 4 Road Erosion Hazard Risk Analysis and Mapping project. The dataset includes combined erosion risk rankings based on a series of constraints, including erodible soils, frequently flooded soils, rivers and streams, wetlands, lakes and ponds, DEM (used to calculate road gradient), slope, and “problem” culverts. The risk factors scored individually and then summarized into “low” (0.5-4 points), “medium” (4.5-6 points) and “high” (≥6.5 points) categories. The state-wide assessment does include limited (but not all, and predominantly longer) private roads and driveways as represented in the E911 Driveways dataset (Section 1.10.4).

The dataset was re-projected from GCS_WGS_1984 to GCS_North_American_1983 and then clipped to the Mad River watershed boundary by using the geoprocessing "clip" function in ArcGIS.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: Erosion_risk_clip

4.7.13 Recreational Trails

Trail routes for downhill ski areas were downloaded from OpenSkiMap.org as Google Earth KMZ files, and converted to ArcGIS feature classes for inclusion in analyses of trails. The OpenSkiMap.org KMZ files contain other, sometimes substantial, base data—including roads, streams, and limited multi-use trails, all in polyline format. Line features that were not classified as ski runs or lifts were deleted from the final dataset.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: OpenSkiMap_MRG_2015_11_11_polylines

Data regarding the routes of mapped multi-use recreational were provided separately by the Mad River Path Association and by consultants to the Mad River Valley Planning District. GIS shapefiles of trail routes provided included:

- Long Trail and network
- Catamount Trail
- Oles Trails
- Municipal trails
- Mad River Riders trails
- Non-public trails
- Mad River Path trails
- Other trails
- Green Mountain National Forest trails
- State-wide trails
- E911 trails

While some of the trail route data provided are definitively public, for some trails, landowners have withheld permission for those trails to be published on any maps. Therefore, while all trail route data are included in relevant analyses, the trail route data cannot be shared or represented on maps.

All of the trails, with the exception of some winter trails and parts of the Catamount Trail, are, basically, single track multi use biking, hiking and skiing/snowshoeing trails. They are unpaved and are only impervious by virtue of the traffic that uses them. In areas where traffic is light, trails have seen very little compaction while in other areas trails have been more compacted. No data are available regarding the current conditions of the trail network. Additionally, these data are only a partial representation of the Mad River Valley's trail network, though they do represent the best currently available data.

Trail segments that were co-located with road segments (e.g., state-wide biking trail routes along VT Routes 100 and 100B) were removed from the dataset. In cases where a trail route was represented in multiple data sources (e.g., overlap between E911 trail routes and Long Trail or Catamount Trail routes), an effort was made to retain only a single trail route. Trail routes that extended beyond the watershed were clipped to the watershed boundary using the geoprocessing "clip" function in ArcGIS.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: Multi_use_trails_merge2_clip

4.7.14 Water Quality and Biomonitoring Data

Water quality data collected by Friends of the Mad River (including total phosphorus (TP, *E. coli*, turbidity), along with the coordinates of the monitoring locations, were downloaded from the Vermont DEC LaRosa Volunteer Monitoring site (https://anrweb.vermont.gov/dec/dec/larosavolmon.aspx). Monitoring location coordinates were converted from the resulting spreadsheet to a points feature class for use in mapping and analysis.

An analysis of the Friends of the Mad River's total phosphorus and turbidity data compared to stream flows measured at the USGS gage at Moretown was completed by Kristen Underwood in February 2016, and provided by the Friends to Stone (full assessment available on request).

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: FMR_WQ_Locations

A GIS shapefile including the locations of all water quality and biomonitoring stations where data have been collected by Vermont DEC and others, as maintained by DEC, was downloaded from the VTANR Open Data website (http://gis.vtanr.opendata.arcgis.com, search for "biomonitoring"). This point file includes the locations of monitoring stations across all DEC monitoring programs, including those where data are collected by Friends of the Mad River, as well as water quality samples and biomonitoring assessments collected or completed by DEC. The final summary result of the most recent macroinvertebrate and fish assessments are included in this dataset; the presence of additional water quality or habitat data is indicated by "yes/no" in the relevant attribute field. Each monitoring location record includes a hyperlink to additional data available on DEC's website, including habitat assessments, fish and macroinvertebrate biomonitoring assessments, and water quality results. While the most recent macroinvertebrate and fish assessment results are included in the attributes of the downloaded dataset, historical water quality results must be accessed and downloaded by individual monitoring station. Assessing this historical dataset is beyond the scope of the current environmental data assessment.

Monitoring locations within the Mad River watershed were extracted from this state-wide dataset by clipping it to the watershed boundary using the geoprocessing "clip" function in ArcGIS.

- Personal Geodatabase: \GISData\Derived\15-214_MRVW3MP.mdb
- Feature Class: DEC_Water_Quality_Locations_clip

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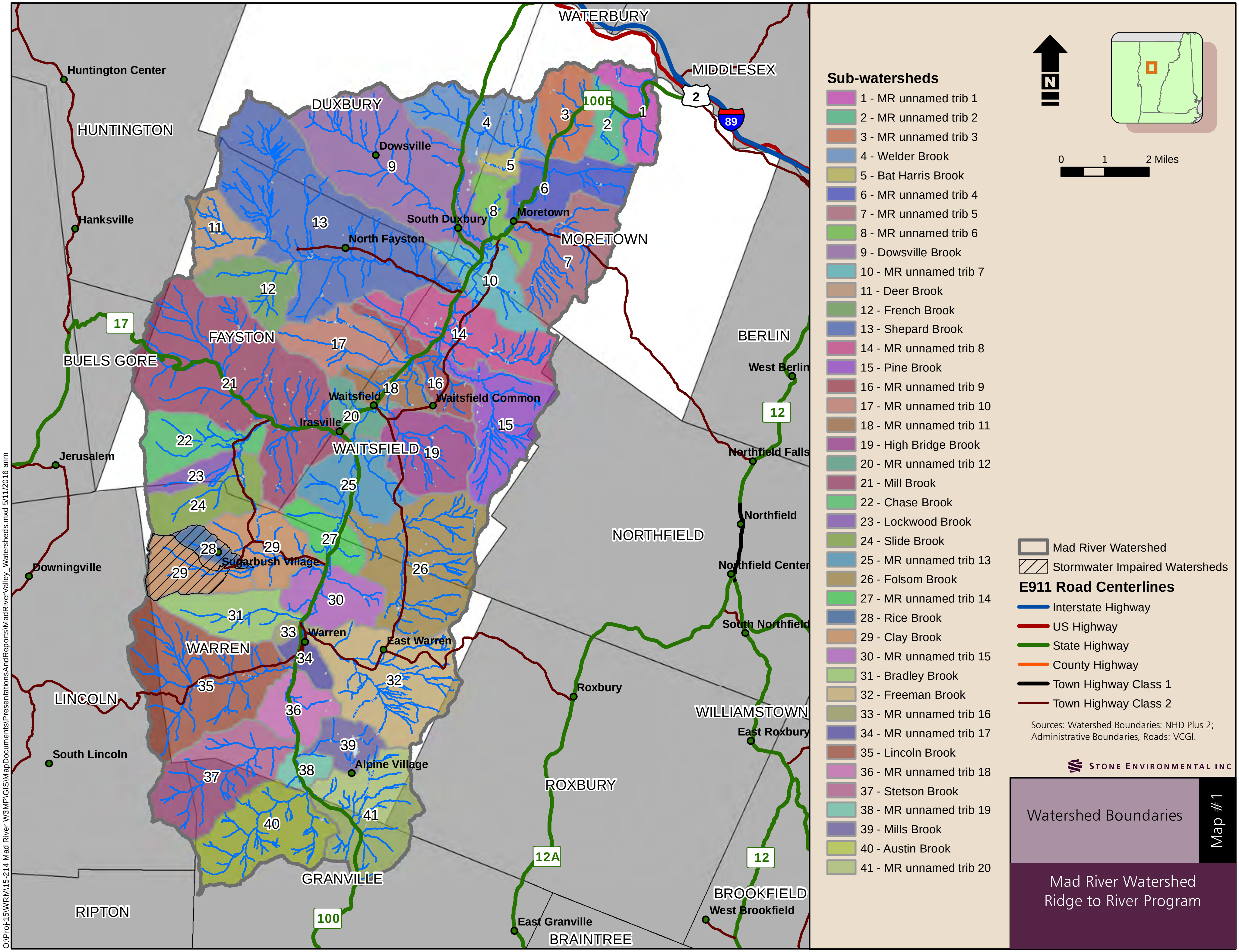

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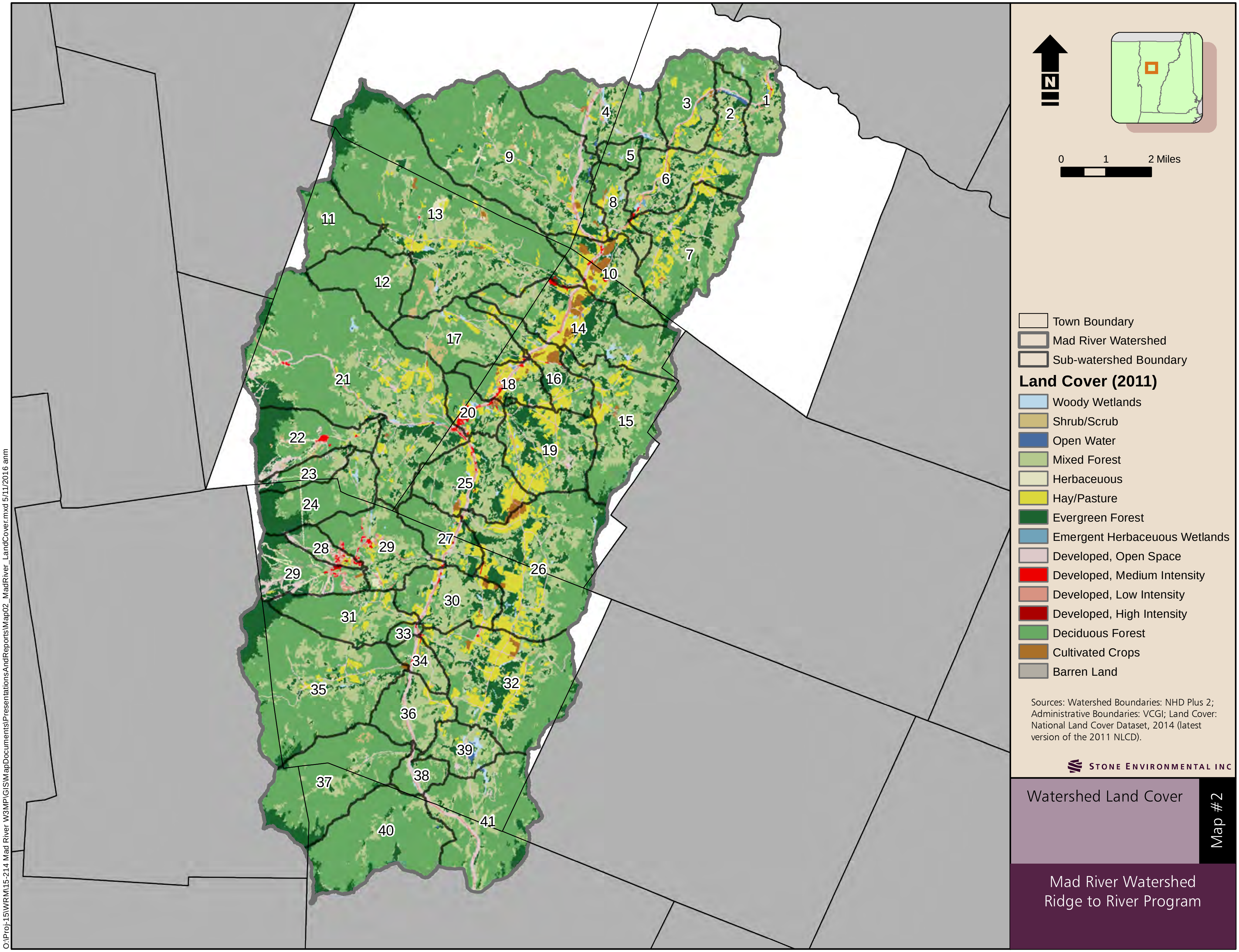

N
0
1
2 Miles
Town Boundary
Mad River Watershed
Sub-watershed Boundary
Land Cover (2011)
Woody Wetlands
Shrub/Scrub
Open Water
Mixed Forest
Herbaceuous
Hay/Pasture
Evergreen Forest
Emergent Herbaceuous Wetlands
Developed, Open Space
Developed, Medium Intensity
Developed, Low Intensity
Developed, High Intensity
Deciduous Forest
Cultivated Crops
Barren Land
Sources: Watershed Boundaries: NHD Plus 2; Administrative Boundaries: VCGI; Land Cover: National Land Cover Dataset, 2014 (latest version of the 2011 NLCD).
Stone Environmental Inc
Watershed Land Cover
Map #2
Mad River Watershed
Ridge to River Program
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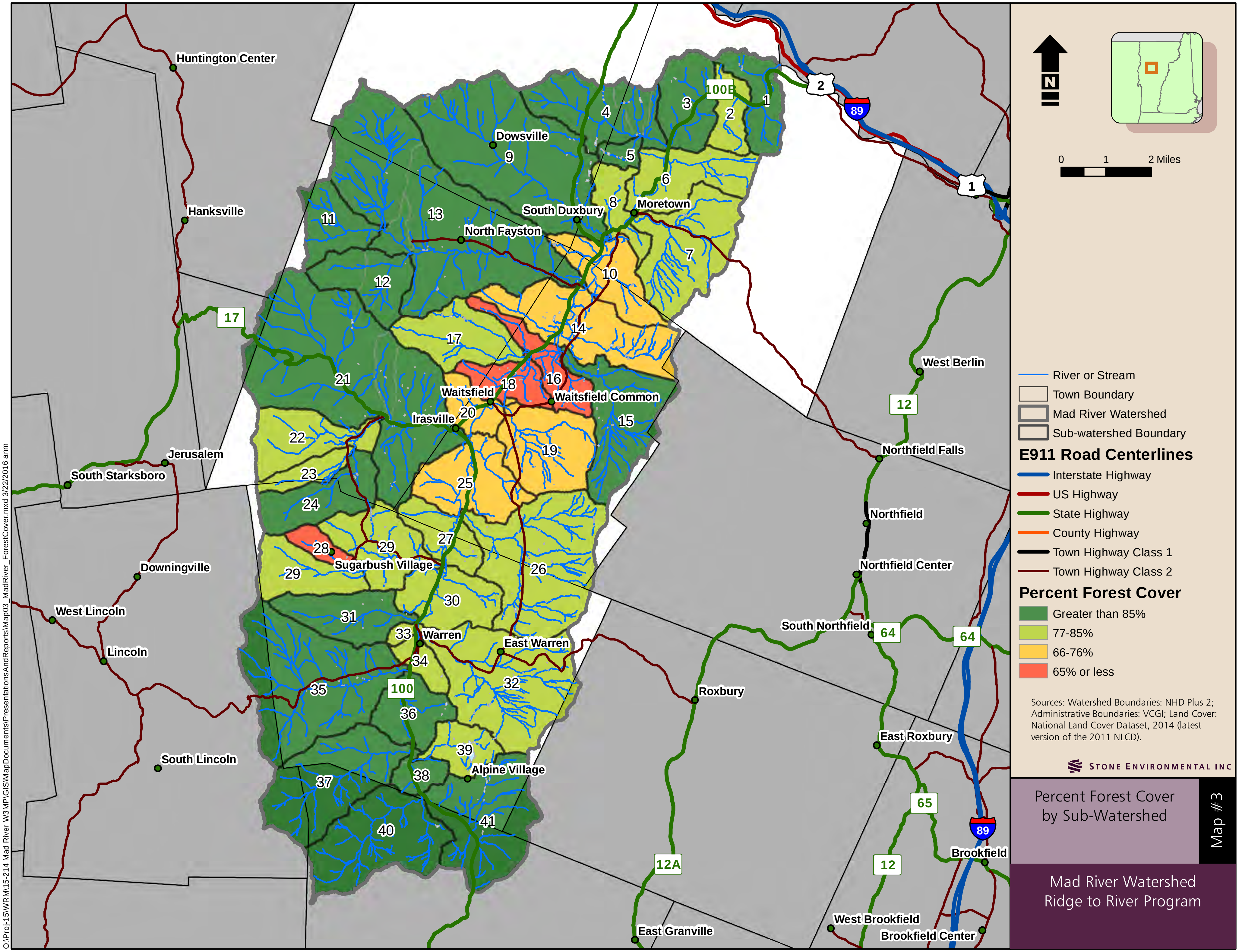

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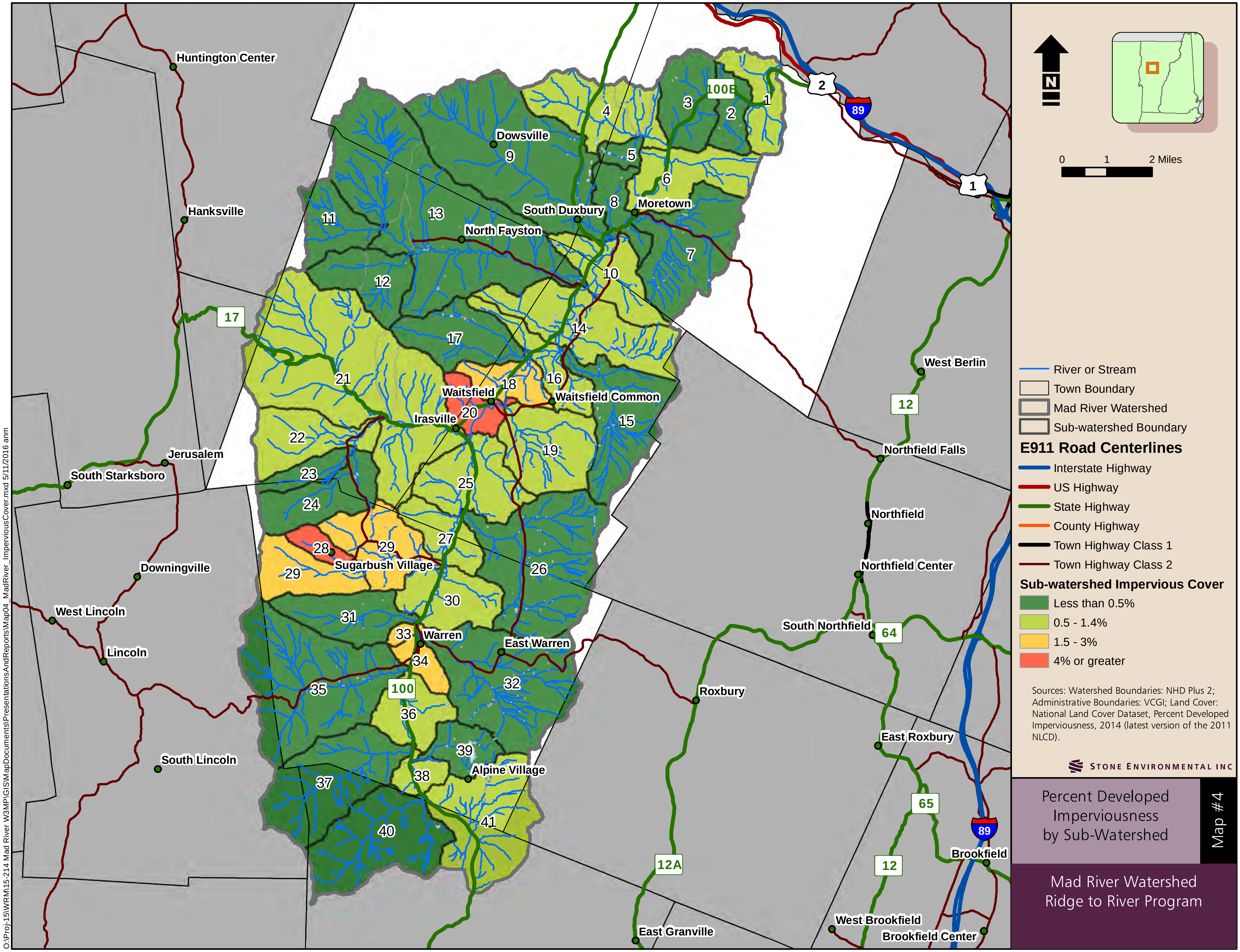

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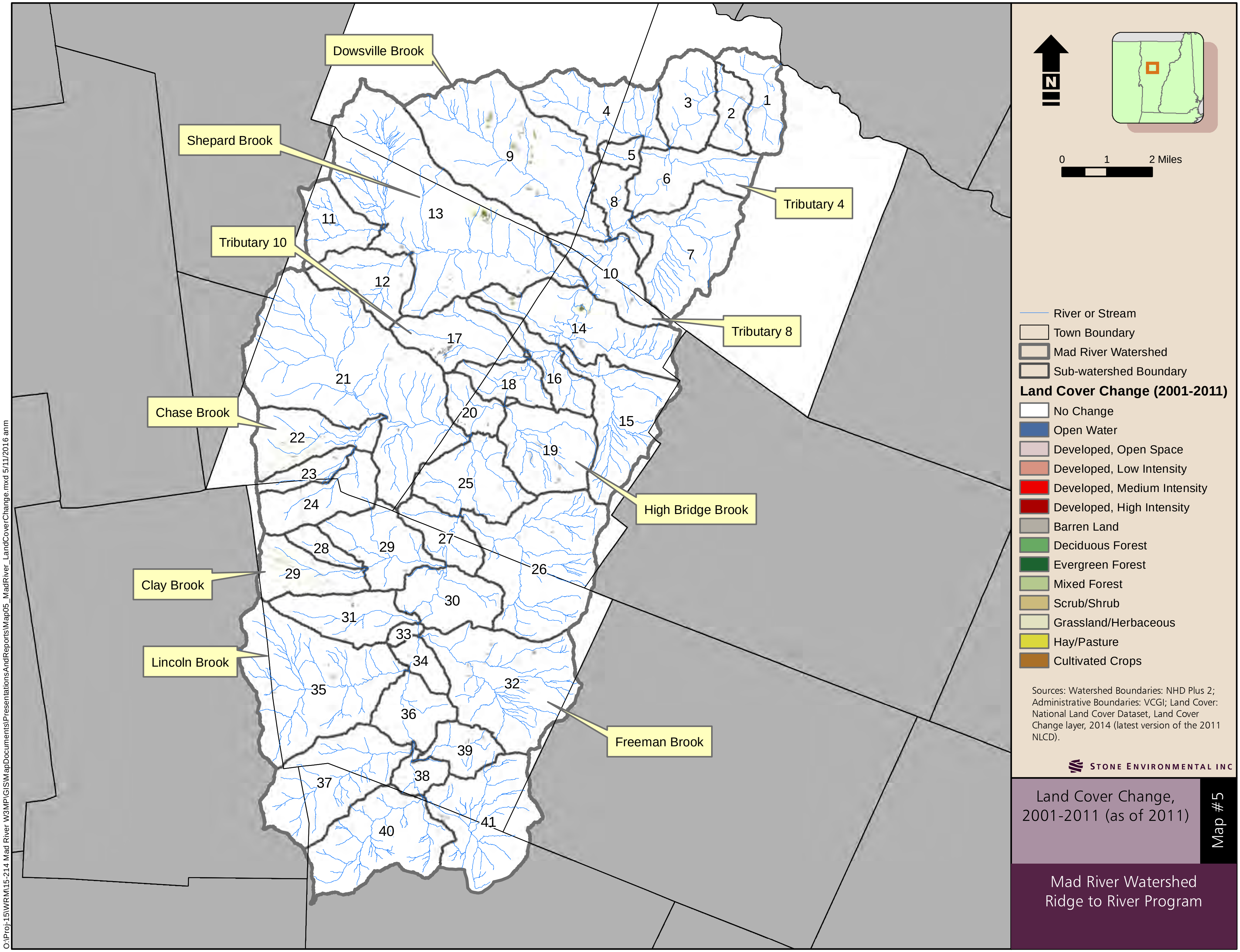

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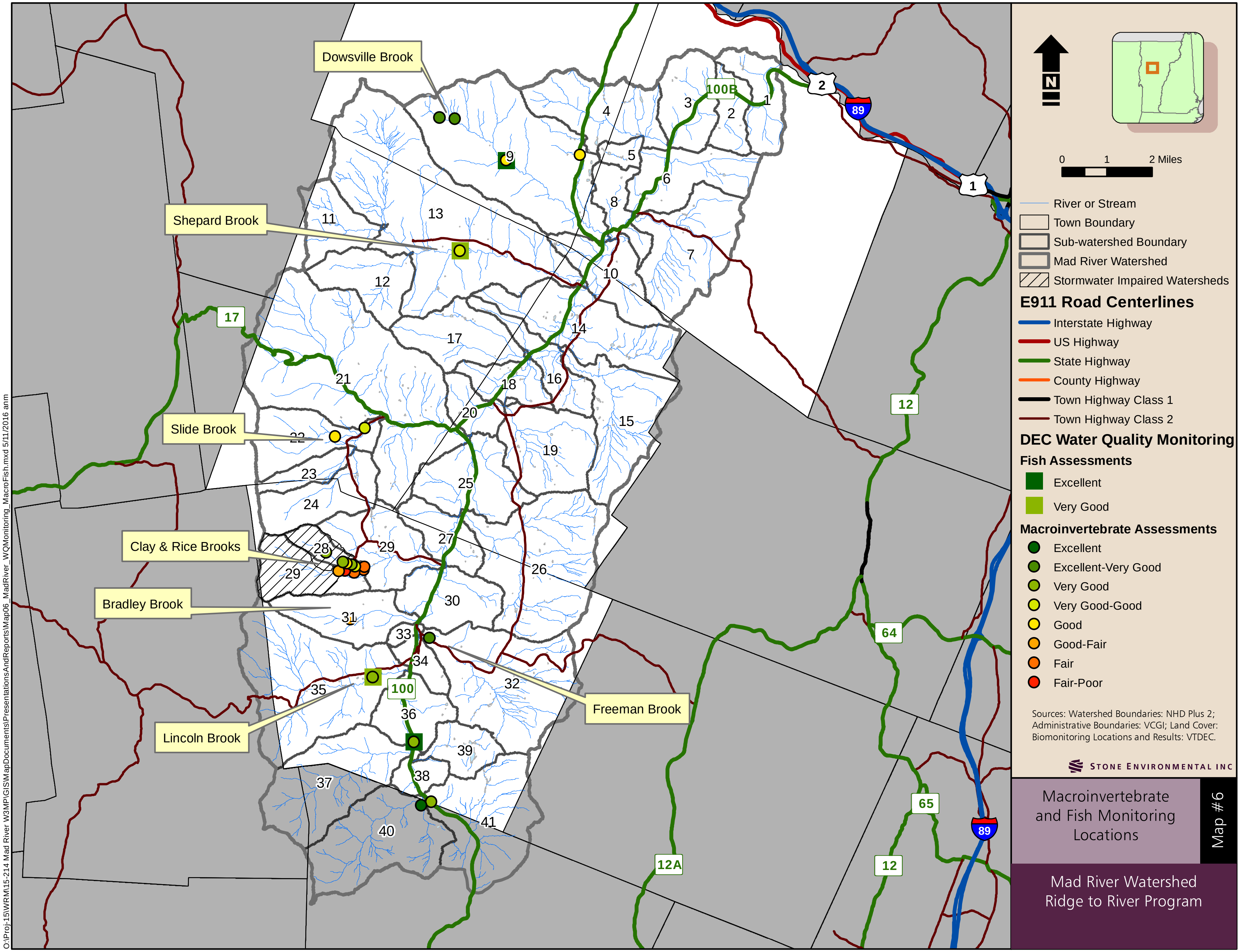

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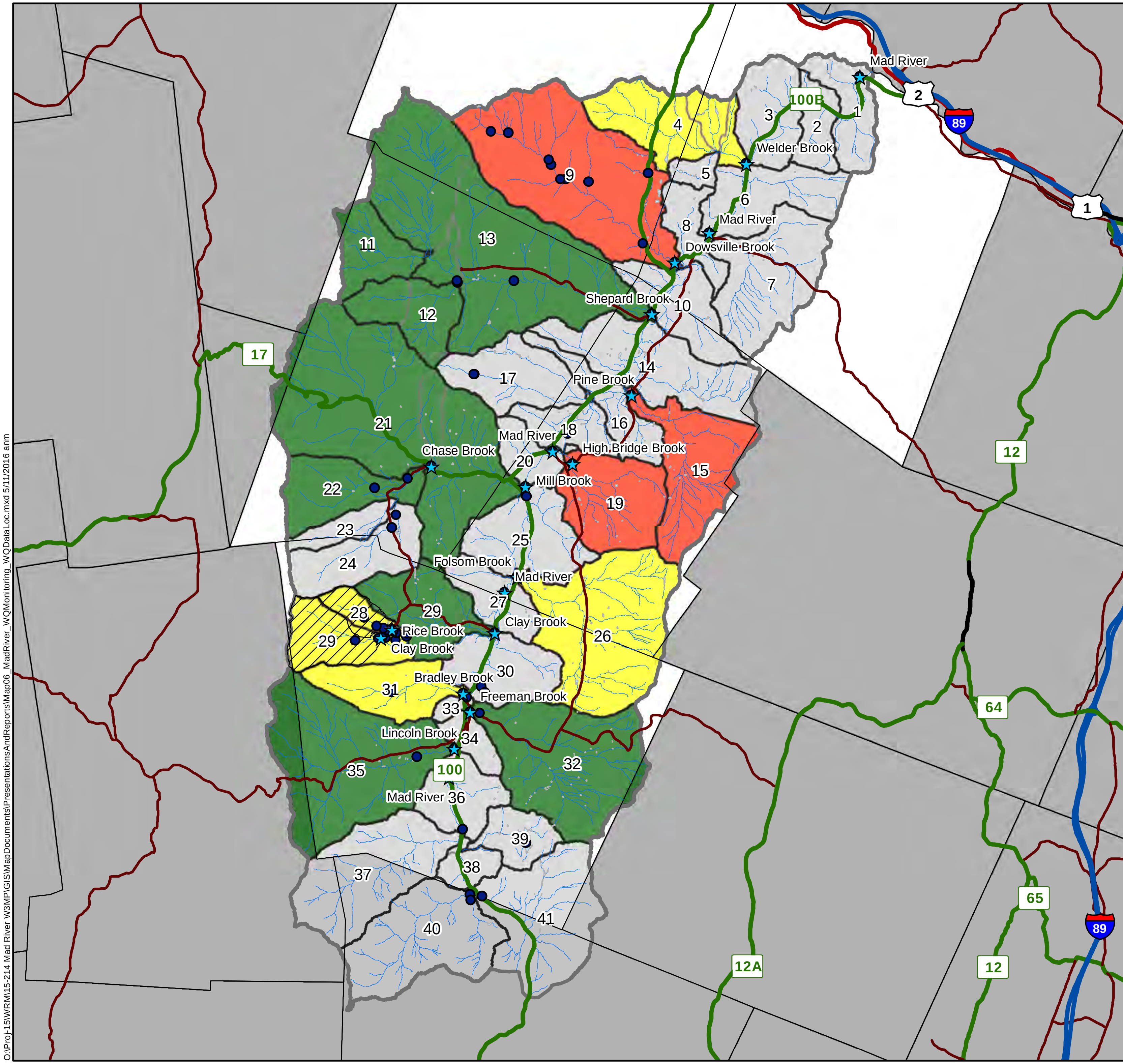


DEC Water Quality Data Available
Friends of the Mad River Monitoring
River or Stream
Town Boundary
Mad River Watershed
Sub-watershed Boundary
Stormwater Impaired Watersheds

E911 Road Centerlines

Interstate Highway
US Highway
State Highway
County Highway
Town Highway Class 1
Town Highway Class 2

FMR Baseflow Analysis

Un-monitored or Mainstem
Meets Water Quality Standards
Mean Total P => WQS
Mean Total P and Turbidity =>WQS

0 1 2 Miles

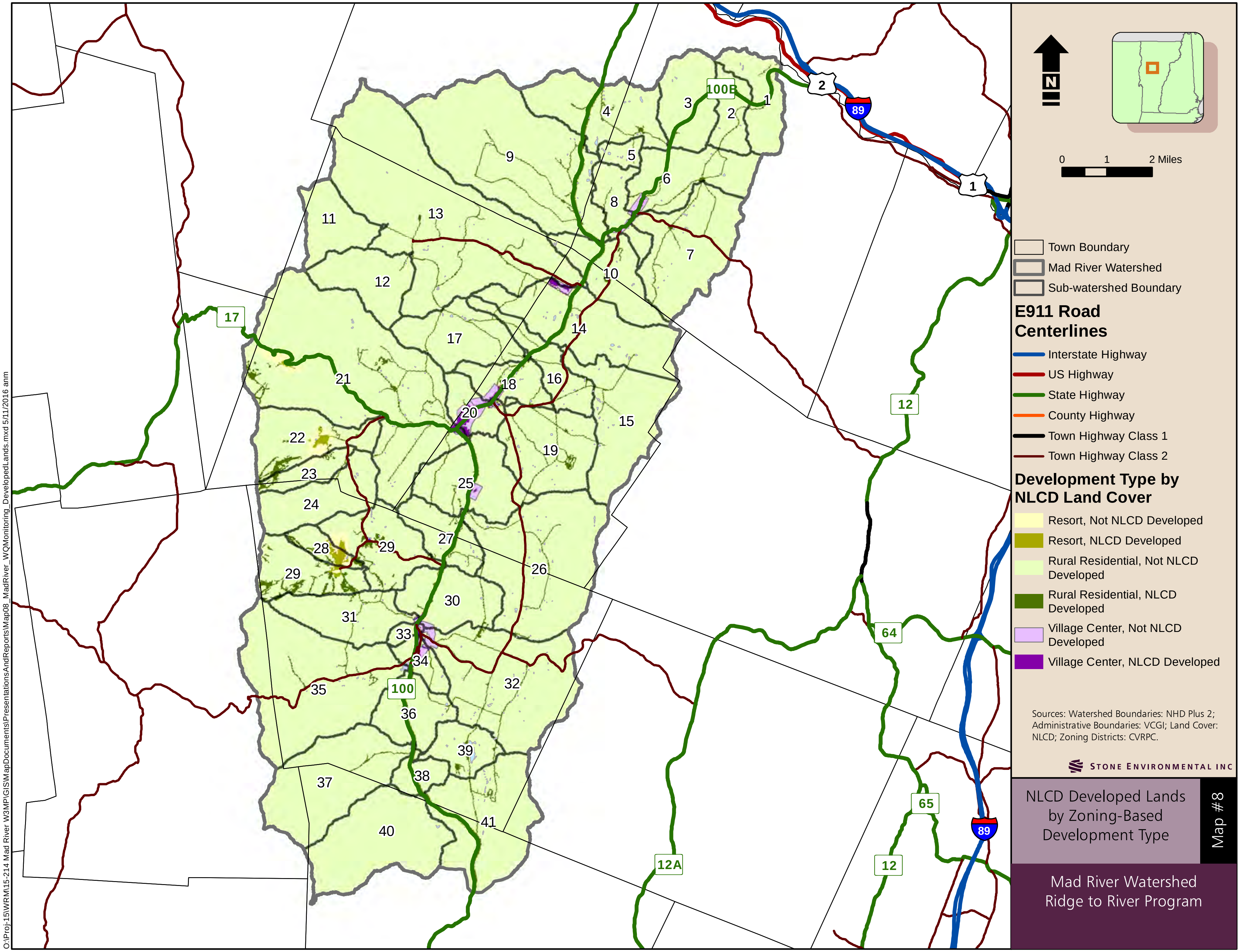
Sources: Watershed Boundaries: NHD Plus 2; Administrative Boundaries: VCGI; Land Cover: Water Quality Monitoring Locations: VTDEC; FMR monitoring locations and data: VTDEC; FMR data analysis results, using data from 2006-2015: Underwood 2016.

STONE ENVIRONMENTAL INC

DEC and Friends of the Mad River (FMR) Water Quality Data Summary

Map #7

Mad River Watershed Ridge to River Program



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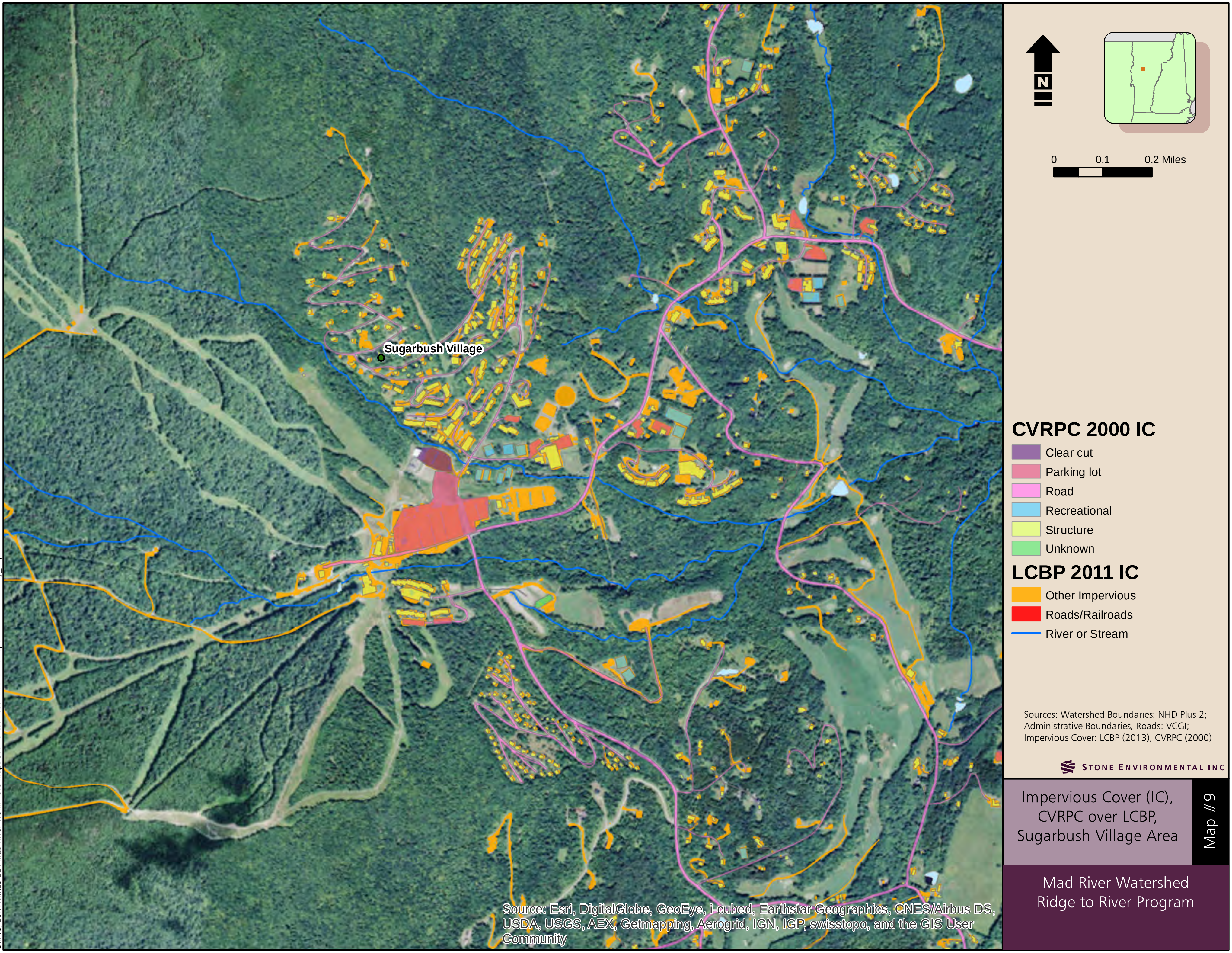
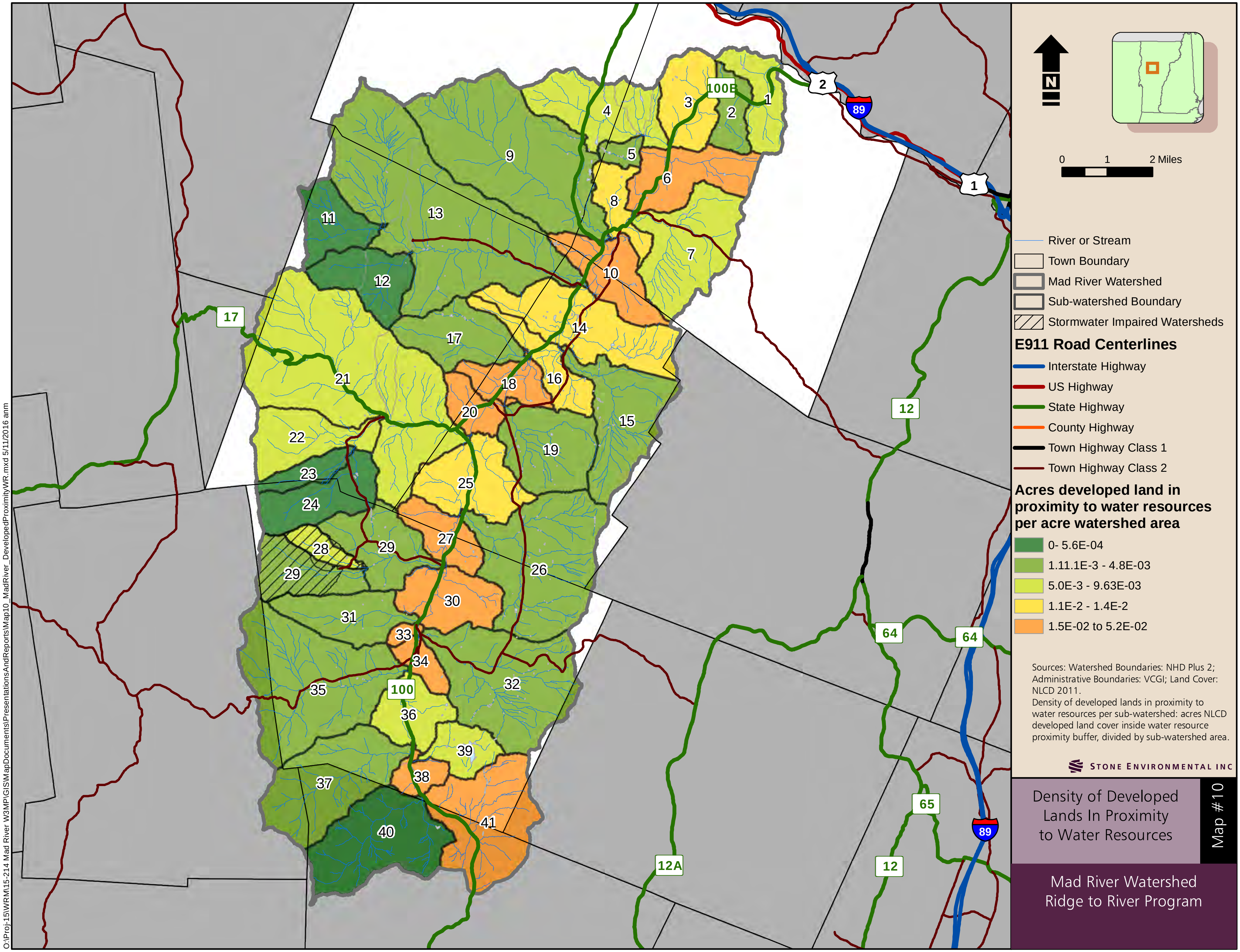
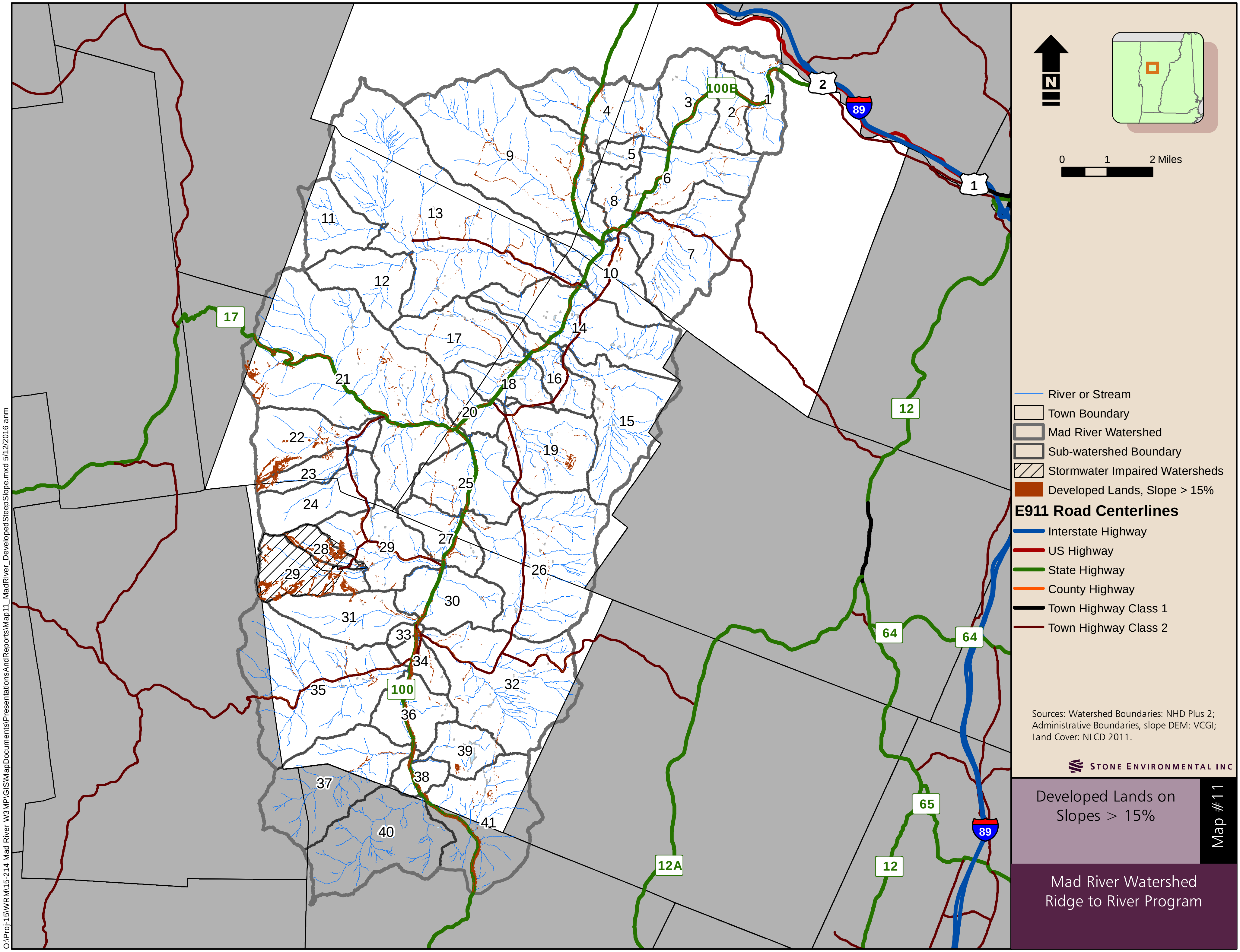


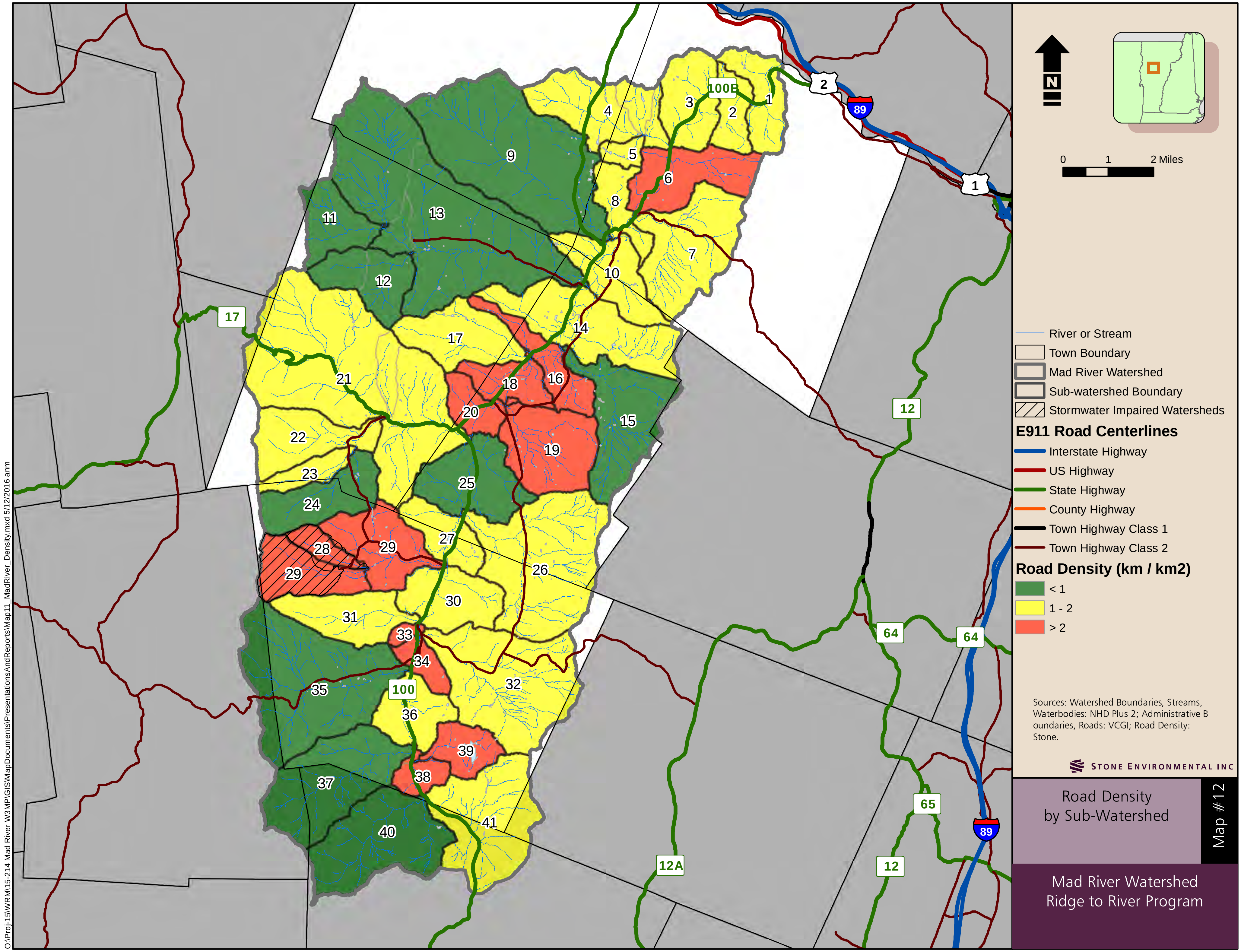
O:\Proj-15\WRM\15-214 Mad River W3MP\GIS\MapDocuments\PresentationsAndReports\MadRiverValley_ImperviousCover.mxd 5/11/2016 anm



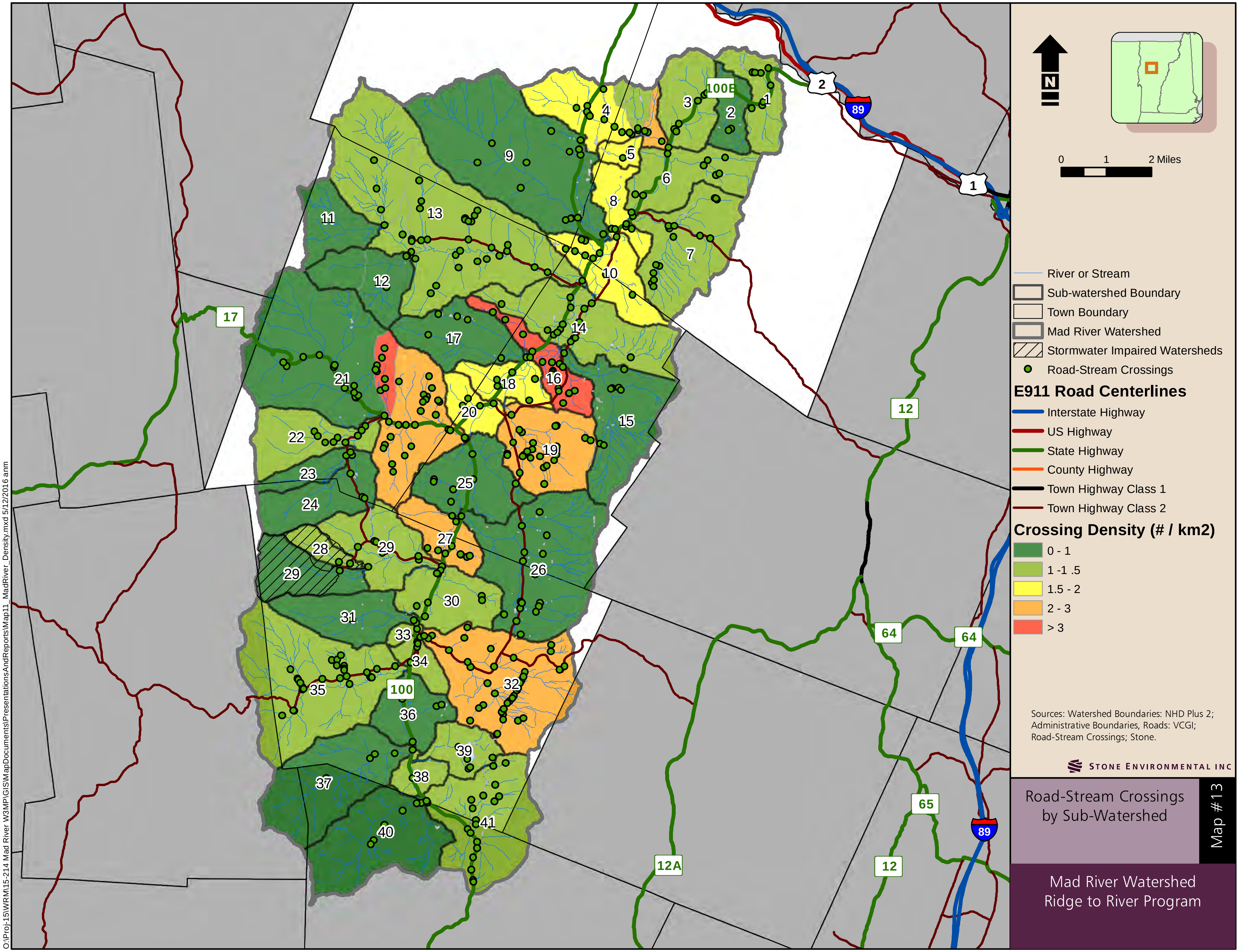
O:\Proj-15\WRM\15-214 Mad River W3MP\GIS\MapDocuments\PresentationsAndReports\Map10_MadRiver_DevelopedProximityWR.mxd 5/11/2016 anm



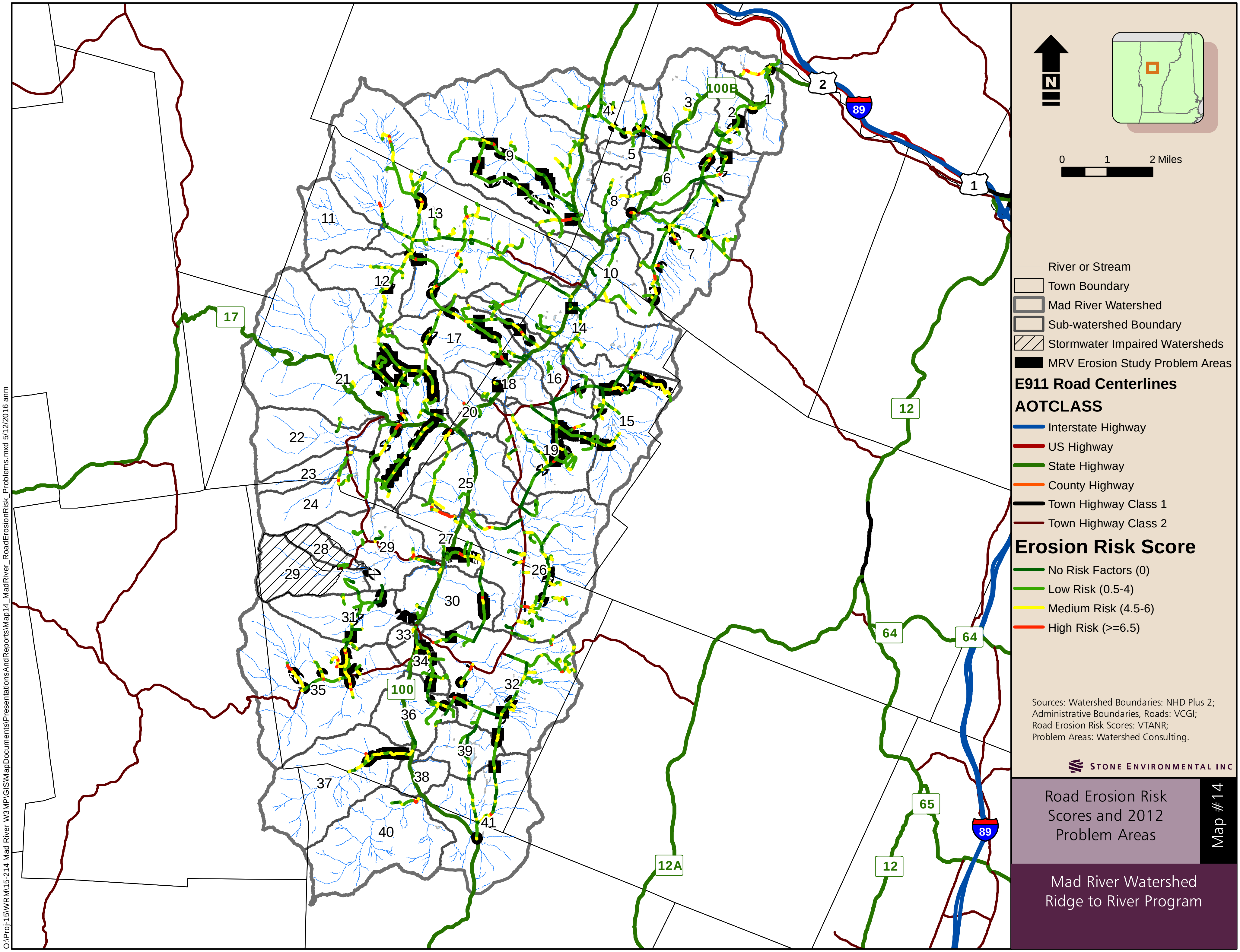
O:\Proj-15\WRM\15-214 Mad River W3MP\GIS\MapDocuments\PresentationsAndReports\Map11_MadRiver_DevelopedSteepSlope.mxd 5/12/2016 anm



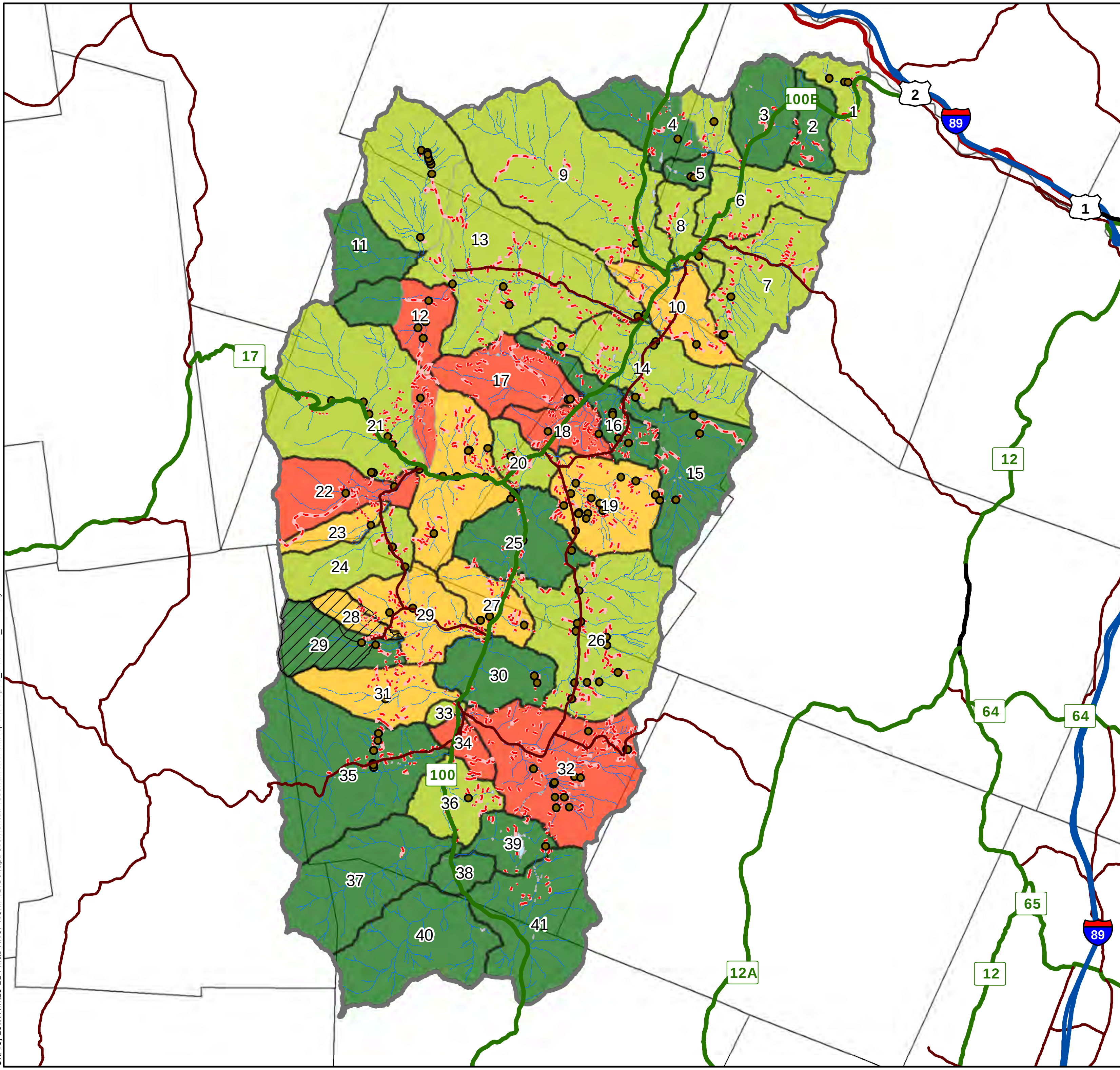
N
0
1
2 Miles
River or Stream
Town Boundary
Mad River Watershed
Sub-watershed Boundary
Stormwater Impaired Watersheds
E911 Road Centerlines
Interstate Highway
US Highway
State Highway
County Highway
Town Highway Class 1
Town Highway Class 2
Road Density (km / km2)
< 1
1 - 2
> 2
Sources: Watershed Boundaries, Streams, Waterbodies: NHD Plus 2; Administrative B oundaries, Roads: VCGI; Road Density: Stone.
Stone Environmental Inc
Road Density by Sub-Watershed
Map #12
Mad River Watershed Ridge to River Program
O:\Proj-15\WRM\15-214 Mad River W3MP\GIS\MapDocuments\PresentationsAndReports\Map11_MadRiver_Density.mxd 5/12/2016 anm
100B
100
17
12
12A
64
65
2
1
89



O:\Proj-15\WRM15-214 Mad River W3MP\GIS\MapDocuments\PresentationsAndReports\Map11_MadRiver_Density.mxd 5/12/2016 anm



O:\Proj-15\WRM\15-214 Mad River W3MP\GIS\MapDocuments\PresentationsAndReports\Map14_MadRiver_RoadErosionRisk_Problems.mxd 5/12/2016 anm



0 1 2 Miles

- River or Stream
- Town Boundary
- Mad River Watershed
- Sub-watershed Boundary
- Stormwater Impaired Watersheds
- Driveway-Stream Crossings

E911 Road Centerlines

- Interstate Highway
- US Highway
- State Highway
- County Highway
- Town Highway Class 1
- Town Highway Class 2
- E911 Driveways (MRV Only)

Steep Driveway Density (km/km2)

- 0 - 0.2
- 0.21 - 0.4
- 0.41 - 0.5
- 0.5 - 0.9

Sources: Watershed Boundaries: NHD Plus 2; Administrative Boundaries, Roads, Driveways: VCGI; Driveway-Stream Crossings, Steep Driveway Density: Stone.

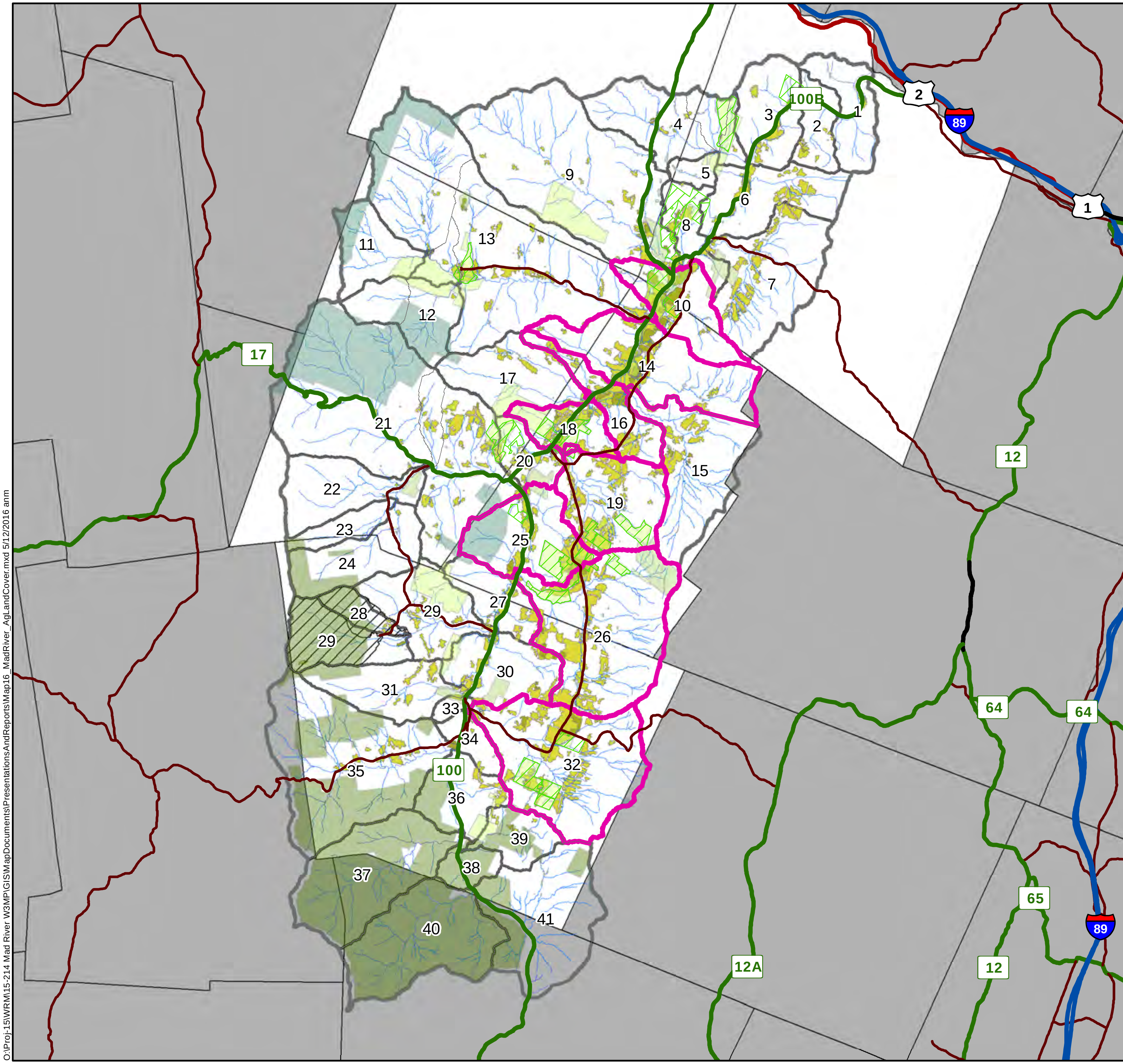
STONE ENVIRONMENTAL INC

Private Driveway Indicators Summary

Map #15

Mad River Watershed Ridge to River Program

O:\Proj-15\WRM15-214 Mad River W3MP\GIS\MapDocuments\PresentationsAndReports\Map15_MadRiver_DrivewayIndicators.mxd 5/12/2016 anm



N

0 1 2 Miles

River or Stream
Town Boundary
Mad River Watershed
Sub-watershed Boundary
Stormwater Impaired Watersheds
Use Value Appraisal Parcels (Ag Land Cover Only)

E911 Road Centerlines

Interstate Highway
US Highway
State Highway
County Highway
Town Highway Class 1
Town Highway Class 2

Conserved Lands

Green Mountain National Forest
State Park, Forest, or WMA
Municipal Conserved Lands
VLT Conserved Lands, Easements

NLCD 2011 Land Cover

Hay/Pasture
Cultivated Crops

% Watershed in Ag Land Cover

Under 15%
15% or More

Sources: Watershed Boundaries: NHD Plus 2; Administrative Boundaries, Roads: VCGI; Conserved Land: UVM/VGCI; Use Value Appraisal parcels: VTANR.

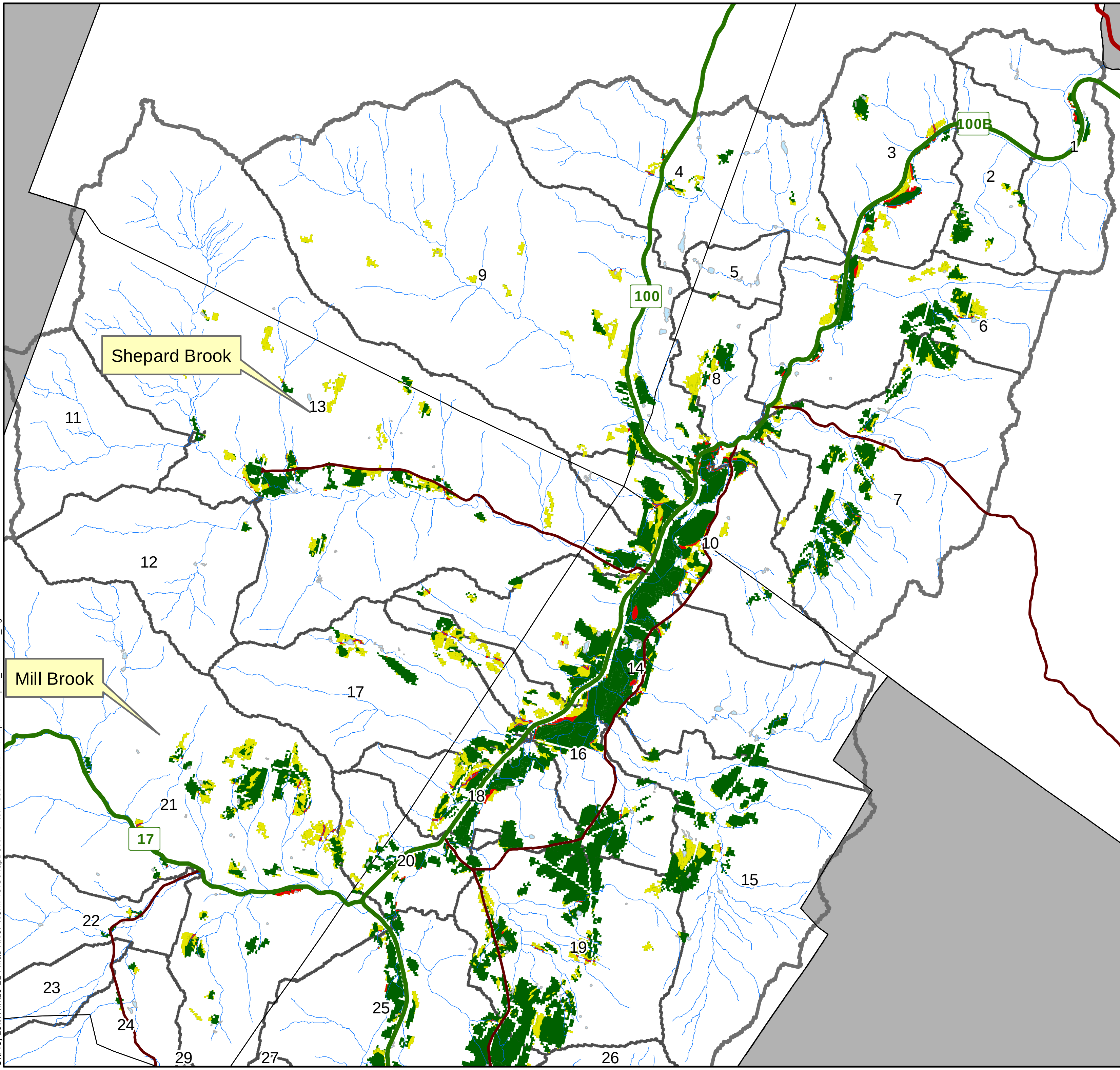
STONE ENVIRONMENTAL INC

Agricultural Land Cover Summary

Map #16

Mad River Watershed Ridge 2 River Program

O:\Proj-15\WRM15-214 Mad River W3MP\GIS\MapDocuments\PresentationsAndReports\Map16_MadRiver_AgLandCover.mxd 5/12/2016 anm



N

0 0.65 1.3 Miles

Sub-watershed Boundary
River or Stream
Town Boundary
Mad River Watershed
Stormwater Impaired Watersheds

E911 Road Centerlines

Interstate Highway
US Highway
State Highway
County Highway
Town Highway Class 1
Town Highway Class 2

NLCD 2011 Agricultural Land Cover Indicators

No Indicators Identified
Slope <15% and/or Highly Erodible Soils
Steep Slope / Erodible Soils Near Water Resource

Sources: Watershed Boundaries: NHD Plus 2; Administrative Boundaries, Roads: VCGI; Land Cover: NLCD 2011; Agricultural Land Cover Indicators: Stone.

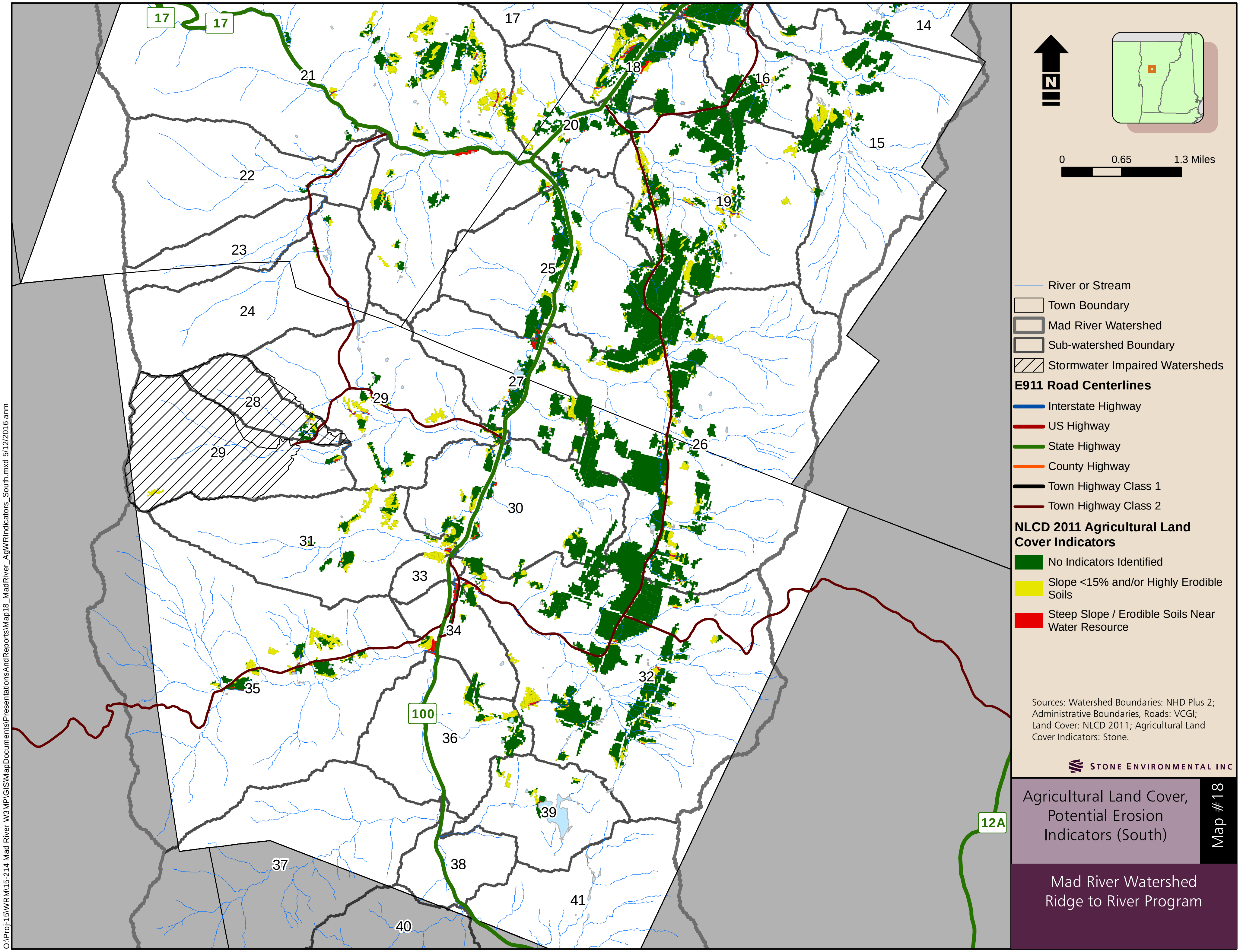
STONE ENVIRONMENTAL INC

Agricultural Land Cover, Potential Erosion Indicators (North)

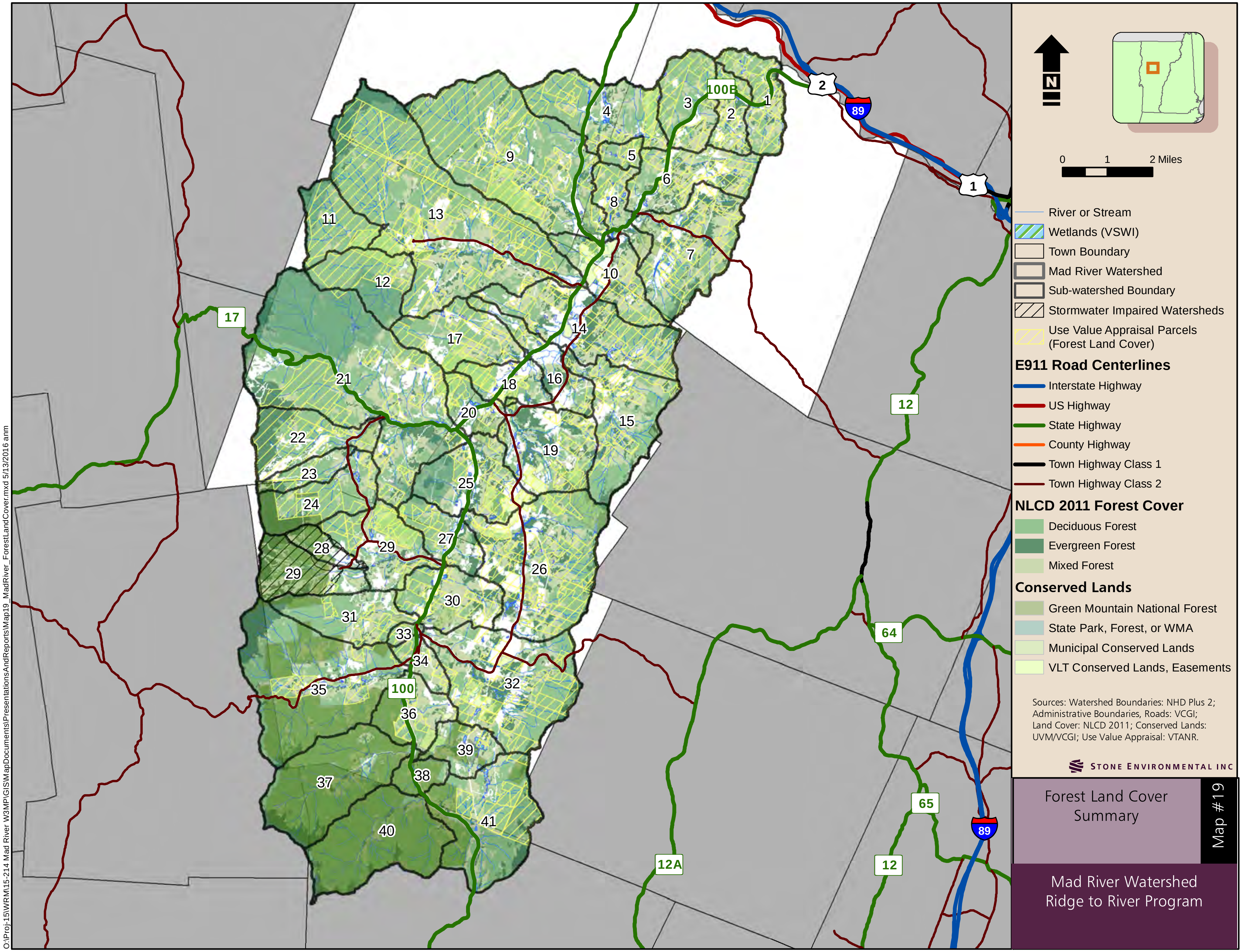
Map #17

Mad River Watershed Ridge to River Program

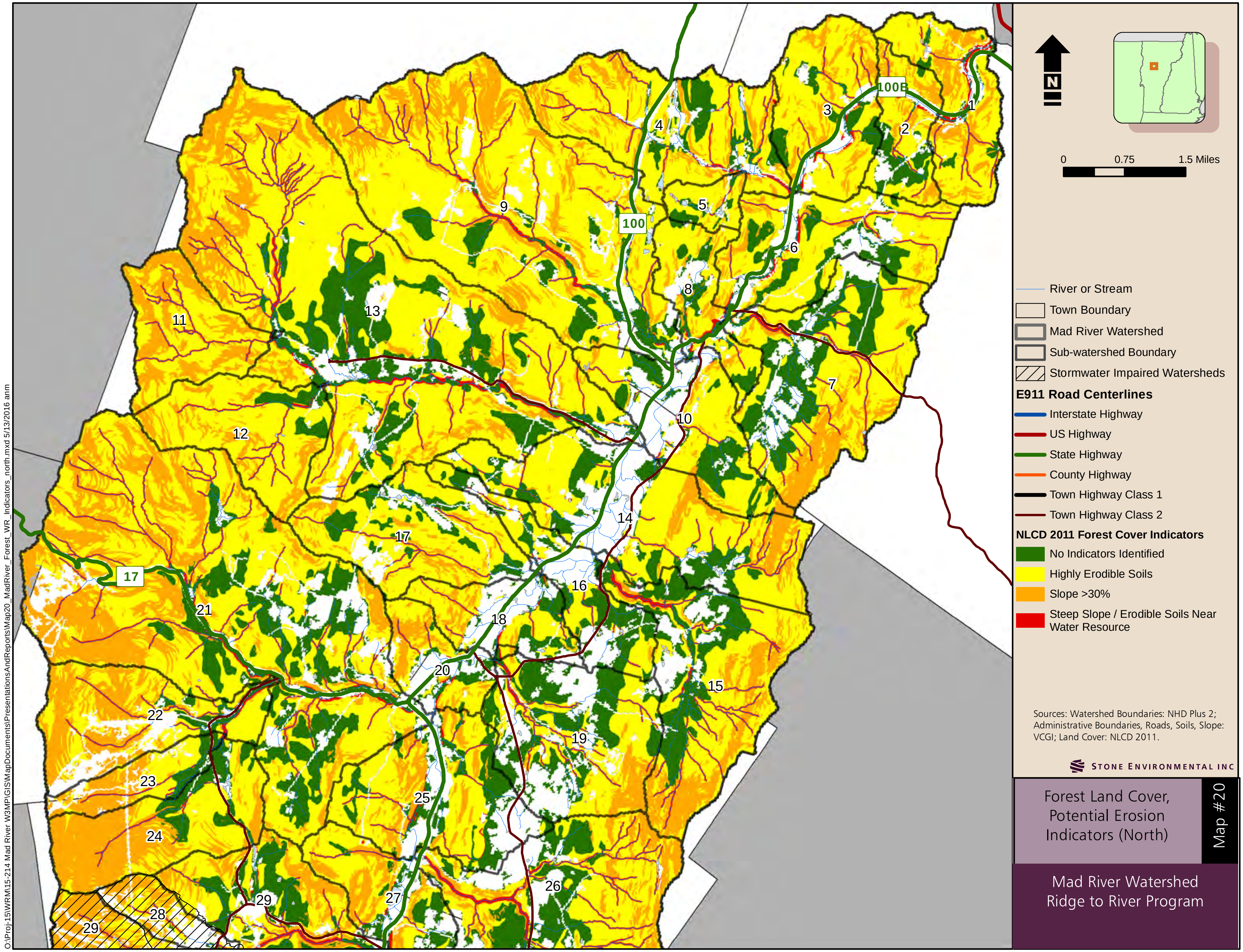
O:\Proj-15\WRM15-214 Mad River W3MP\GIS\MapDocuments\PresentationsAndReports\Map16_MadRiver_AgWRIndicators.mxd 5/12/2016 anm



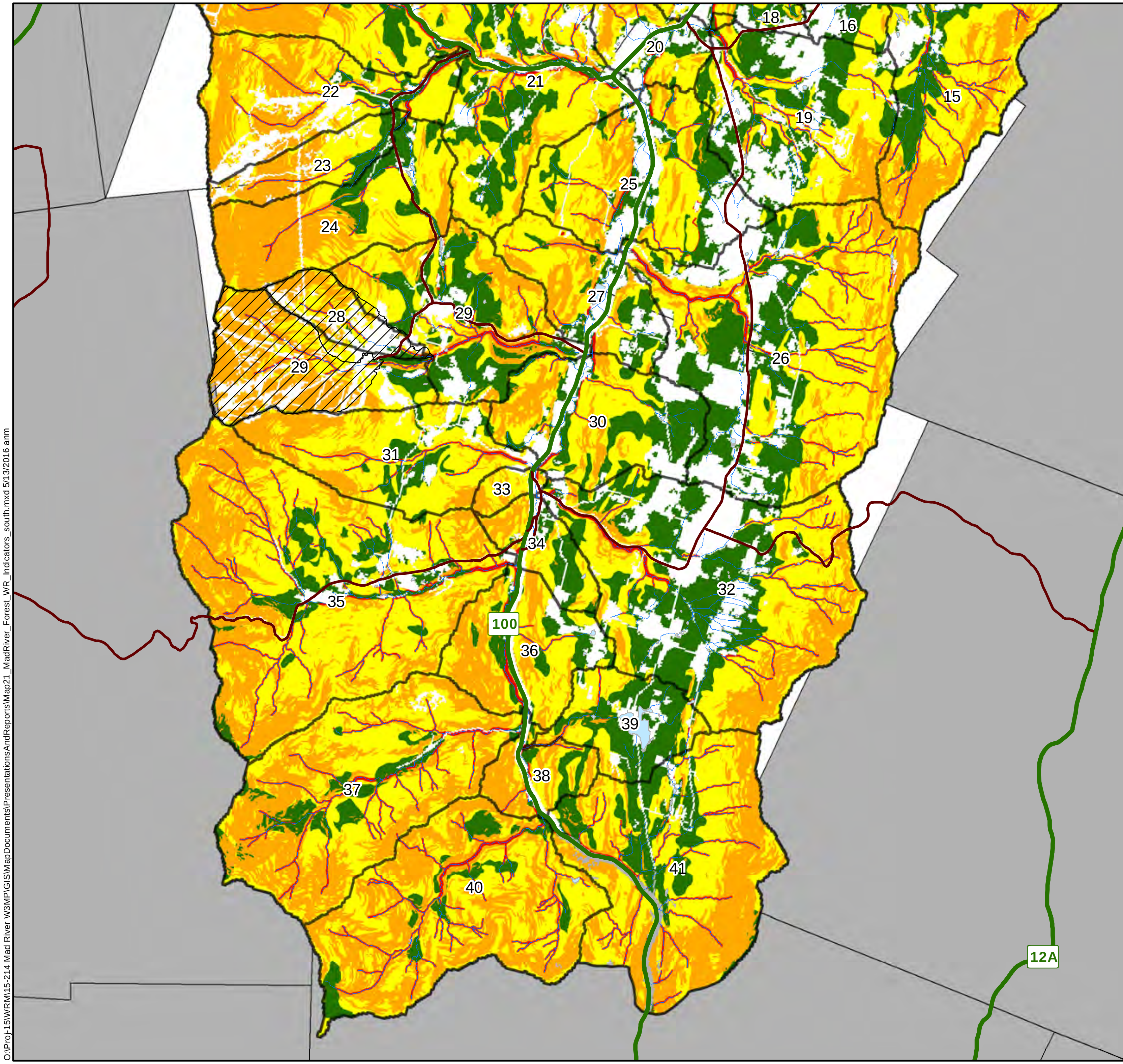
O:\Proj-15\WRM15-214 Mad River W3MP\GIS\MapDocuments\PresentationsAndReports\Map18_MadRiver_AgWRIndicators_South.mxd 5/12/2016 anm



O:\Proj-15\WRM\15-214 Mad River W3MP\GIS\MapDocuments\PresentationsAndReports\Map19_MadRiver_ForestLandCover.mxd 5/13/2016 anm



100B
100
17
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
29
N
0
0.75
1.5 Miles
River or Stream
Town Boundary
Mad River Watershed
Sub-watershed Boundary
Stormwater Impaired Watersheds
E911 Road Centerlines
Interstate Highway
US Highway
State Highway
County Highway
Town Highway Class 1
Town Highway Class 2
NLCD 2011 Forest Cover Indicators
No Indicators Identified
Highly Erodible Soils
Slope >30%
Steep Slope / Erodible Soils Near Water Resource
Sources: Watershed Boundaries: NHD Plus 2; Administrative Boundaries, Roads, Soils, Slope: VCGI; Land Cover: NLCD 2011.
STONE ENVIRONMENTAL INC
Forest Land Cover, Potential Erosion Indicators (North)
Map #20
Mad River Watershed Ridge to River Program
O:\Proj-15\WRM\15-214 Mad River W3MP\GIS\MapDocuments\PresentationsAndReports\Map20_MadRiver_Forest_WR_Indicators_north.mxd 5/13/2016 anm



0 0.75 1.5 Miles

- River or Stream
- Town Boundary
- Mad River Watershed
- Sub-watershed Boundary
- Stormwater Impaired Watersheds

E911 Road Centerlines

- Interstate Highway
- US Highway
- State Highway
- County Highway
- Town Highway Class 1
- Town Highway Class 2

NLCD 2011 Forest Cover Indicators

- No Indicators Identified
- Highly Erodible Soils
- Slope >30%
- Steep Slope / Erodible Soils Near Water Resource

Sources: Watershed Boundaries: NHD Plus 2; Administrative Boundaries, Roads, Soils, Slope: VCGI; Land Cover: NLCD 2011.

STONE ENVIRONMENTAL INC

Forest Land Cover, Potential Erosion Indicators (South)

Map #21

Mad River Watershed Ridge to River Program

O:\Proj-15\WRM15-214 Mad River W3MP\GIS\MapDocuments\PresentationsAndReports\Map21_MadRiver_Forest_WR_Indicators_south.mxd 5/13/2016 anm