Moretown, Vermont
Phase 2 Stream Geomorphic Assessment & River Corridor Plan

April 20, 2018

Prepared by:
Bear Creek Environmental, LLC
149 State Street, Suite 3
Montpelier, Vermont 05602

Prepared under contract to:
Central Vermont Regional Planning Commission
29 Main Street, Suite 4
Montpelier, VT 05602

Funding for this project was provided by:
State of Vermont Ecosystem Restoration Program

Moretown, Vermont
Phase 2 Stream Geomorphic Assessment & River Corridor Plan

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY 1

2.0 LOCAL PLANNING PROGRAM OVERVIEW 3

2.1 Overview 3
2.2 River Corridor Planning Team 3
2.3 Local Project Objectives 4
2.4 Goals of the Vermont River Management Program 4

3.0 BACKGROUND WATERSHED INFORMATION 5

3.1 Watershed Description 5
3.2 Geomorphic Setting 5
3.3 Hydrology 8

4.0 METHODS 11

4.1 Phase 1 Methodology 11
4.2 Phase 2 Methodology 11
4.3 Bridge and Culvert Methodology 12
4.4 Condition and Departure Analysis 13
4.4.1 Stream Types 13
4.4.2 Geomorphic Condition 14
4.4.3 Habitat Condition 14
4.4.4 Sediment Regime 14
4.4.5 Channel Evolution Model 15

5.0 RESULTS 16

5.1 Reach/Segment Descriptions 17
5.2 Stream Crossings 47

6.0 PRELIMINARY PROJECT IDENTIFICATION 47

6.1 Project Identification 47
6.2 Program Descriptions 49
6.3 Next Steps 53

7.0 LIST OF ACRONYMS AND GLOSSARY OF TERMS 55

8.0 REFERENCES 61

Appendices

Appendix A – Maps
Appendix B – Bridge & Culvert Assessment Data
Appendix C – Potential Project Locations & Descriptions

Bear Creek Environmental, LLC

149 State Street, Suite 3 / Montpelier, VT 05602

Phone: (802) 223-5140 / **Web:** www.BearCreekEnvironmental.com

Moretown, Vermont
Phase 2 Stream Geomorphic Assessment & River Corridor Plan

1.0 EXECUTIVE SUMMARY

A stream geomorphic assessment within the Mad River and middle Winooski River watersheds was conducted by Bear Creek Environmental, LLC (BCE) under the direction of Central Vermont Regional Planning Commission (CVRPC) and the Vermont Agency of Natural Resources (VANR) during the summer and fall of 2017. Funding for the project was provided through the State of Vermont Ecosystem Restoration Program. A planning strategy based on fluvial geomorphic science (see glossary at end of report for associated definitions) was chosen because it provides a holistic, watershed-scale approach to identifying the stressors on river ecosystem health. The stream geomorphic assessment data can be used by resource managers, community watershed groups, municipalities and others to identify how changes to land-use alter the physical processes and habitat of rivers.

The Town of Moretown, Vermont experienced major flooding in August 2011 and subsequent damage to infrastructure as a result of Tropical Storm Irene (TSI). As part of the long-term plan to mitigate the impact of flooding, improve aquatic habitat, and increase river stability, Central Vermont Regional Planning Commission secured state funding to complete a Phase 2 stream geomorphic assessment for several streams within the town. The stream geomorphic assessment data will be used to help focus stream restoration and protection activities within the watershed and assist the town with flood resiliency planning.

The study encompassed approximately 11 miles of stream channel within 13 reaches on the Mad River, Welder Brook, Dowsville Brook, Jones Brook, Kelley Brook, and Herring Brook. This stream geomorphic assessment facilitated the identification of major stressors to geomorphic stability and habitat conditions within the study area. The predominant stressor observed for these streams is stream channel straightening and corridor encroachment associated with the existence of roads and development. In many cases, this encroachment has limited floodplain access and has caused moderate to extreme channel degradation (lowering of the bed) resulting in sediment build up, channel widening, and planform adjustment (lateral movement). Numerous state and town highways were historically built into river valleys throughout the study area, including critical travel routes such as Vermont Routes 100 and 100B. The Village of Moretown, a hub of residential and municipal activity, lies within the Mad River Valley.

Following Tropical Storm Irene, immense recovery efforts were undertaken to repair roads, buildings, and other infrastructure that were damaged by the flooding. Moving forward, it is important for communities to continually prepare for the next flood by taking steps to become

more flood resilient. This report outlines strategies that can be implemented on both site-specific and community-wide levels to mitigate flood damage and losses in the future.

The river corridor planning effort in Moretown is a continuous and collaborative process. The stream geomorphic assessment data collected in this study build on other data that have been collected throughout the Mad River and Winooski River watersheds in the past decade. Analysis of these data has aided the identification of major impacts and stressors and the development of projects to mitigate impacts, increase geomorphic stability, and improve aquatic habitat.

A list of 43 potential restoration, conservation, and flood resiliency projects was developed using the stream geomorphic assessment data collected within the study area. The projects fall within five categories, as outlined by the Vermont Watershed Management Division in its Watershed Projects Database table:

Project Category	Number of Proposed Projects
Agricultural Pollution Prevention - Preliminary Design	2
Dam Removal - Preliminary Design	1
Floodplain/Stream Restoration - Preliminary Design	17
River - Planting	17
River Corridor Easement - Design	6
Total Number of Projects	**43**

Types of projects include river corridor easements, riparian buffer improvements, berm removals, bridge and culvert replacements, dam removal, and more. Potential projects will be prioritized based on several factors, including ease of implementation, cost, landowner interest, effectiveness, and site-specific factors. Further project development, including additional data collection, may be required for project design, permitting, and implementation.

2.0 LOCAL PLANNING PROGRAM OVERVIEW

There are many scientific terms used in this river corridor plan, and the reader is encouraged to refer to the glossary at the end of the document. Important terms that are in the glossary are shown in italics the first time they are used in the text.

2.1 Overview

This project focuses on the Winooski River watershed in the town of Moretown, Vermont, although small sections of Duxbury and Berlin are also included. The study area is comprised of two watersheds that drain to the Winooski River – the Mad River watershed and the Jones Brook watershed.

The Mad River and several of its *tributaries*, as well as Jones Brook and two of its tributaries, were assessed during the summer and fall of 2017 using the Vermont Agency of Natural Resources Phase 2 Stream Geomorphic Assessment protocol. Mad River tributaries included in this assessment are Welder Brook, Doctors Brook, and Dowsville Brook. Jones Brook tributaries that underwent assessment are Kelley Brook and Herring Brook.

Phase 2 geomorphic assessments have occurred in numerous areas in the Mad River and Winooski River watersheds within the past decade. Corridor plans for other phase 2 assessment areas can be found at https://anrweb.vt.gov/DEC/SGA/finalReports.aspx.

The Vermont Rivers Program has developed state-of-the-art Stream Geomorphic Assessment (SGA) protocols that utilize the science of *fluvial geomorphology* (fluvial = water, geo = earth, and morphology = the study of structure or form). Fluvial geomorphology focuses on the processes and pressures operating on river systems. The Vermont protocol includes three phases:

1. Phase 1 – Remote sensing and cursory field assessment;
2. Phase 2 – Rapid habitat and rapid geomorphic assessments to provide field data to characterize the current physical condition of a river; and
3. Phase 3 – Detailed survey information for designing "active" channel management projects.

2.2 River Corridor Planning Team

The river corridor planning team for this stream geomorphic assessment is comprised of Central Vermont Regional Planning Commission (CVRPC), Bear Creek Environmental (BCE), the Vermont Agency of Natural Resources (VANR), the Town of Moretown, the Friends of the Mad River, and the Friends of the Winooski River. The 2017 study was funded through The State of Vermont Ecosystem Restoration Program under contract to Central Vermont Regional Planning Commission. Gretchen Alexander from the Vermont River Management Program of VANR provided a quality control/assurance review of the stream geomorphic assessment data, as well as assistance with field work, and the Central Vermont Regional Planning Commission assisted with the field work and provided the overall project coordination.

2.3 Local Project Objectives

The stream geomorphic assessment data are useful to resource managers, community watershed groups, municipalities and others for identifying how changes to land-use alter the physical processes and *habitat* of rivers. Characterizing stream type, identifying stressors in the watershed, and assessing the health of aquatic habitat and the riparian corridor are essential for the preparation of an effective and long-term river corridor plan. Central Vermont Regional Planning Commission and project partners, in collaboration with towns and other organizations, have the opportunity to address and mitigate major watershed stressors through the design and implementation of *restoration* and protection projects outlined in this corridor plan.

The Water Quality Management Plan (WQMP) for Basin 8 (Winooski River) outlines several strategies to restore and protect all surface waters within the Winooski River watershed. Goals in the Winooski River basin include improving water quality, protecting habitat, and reducing river-development conflicts. There are numerous reaches within the Winooski River watershed that have impaired water quality. Specific to the study area, the basin plan identifies that bacterial contamination is an issue on the Mad River from the mouth to Moretown (Vermont Agency of Natural Resources, 2012b).

2.4 Goals of the Vermont River Management Program

The State of Vermont's Rivers Program has set out several goals and objectives that are supportive of the local initiative in Moretown. The state management goal is to, "manage toward, protect, and restore the fluvial geomorphic equilibrium condition of Vermont rivers by resolving conflicts between human investments and river dynamics in the most economically and ecologically sustainable manner" (Vermont Agency of Natural Resources, 2009b). The objectives of the Program include *fluvial erosion* hazard mitigation and sediment and nutrient load reduction, as well as aquatic and riparian habitat protection and restoration. The Program seeks to conduct river corridor planning in an effort to remediate the geomorphic instability that is largely responsible for problems in a majority of Vermont's rivers. The Vermont River Management Program has set out to provide funding and technical assistance to facilitate an understanding of river instability and the establishment of well-developed and appropriately scaled strategies to protect and restore river equilibrium. Additionally, the Program is currently in the process of developing an updated Tactical Basin Plan for the Winooski watershed. This corridor plan will fulfill specific actions outlined in the tactical basin plan. It also supports goals included in the Lake Champlain Phosphorus Total Maximum Daily Load (TMDL) under Act 64.

3.0 BACKGROUND WATERSHED INFORMATION

3.1 Watershed Description

The Winooski River begins in Cabot, Vermont and flows for approximately 90 miles before entering Lake Champlain in Colchester, Vermont. The Mad River is a 28 mile long river that drains roughly 144 square miles. It begins in the town of Granville and flows north through Warren, Waitsfield, and Moretown, where it meets the Winooski River. Jones Brook is a smaller tributary to the Winooski River with a watershed size of only 10 square miles. It originates in Moretown and flows through Berlin where it meets the Winooski River 4.5 river miles later (VANR, 2017). The location of the study watersheds is shown below in Figure 3.1.

The Mad River and Jones Brook watersheds are located in the Northern Green Mountain biophysical region. This region is characterized by Thompson and Sorenson (2000) as an area of high elevations, which includes Vermont's tallest peaks. These mountains greatly influence the climate of the region. Precipitation is abundant in this region, and temperatures are colder than in other areas due to higher elevations. The typical zonation of forest types can be found in this biophysical region. From the lower slopes to the summits, Northern Hardwood Forest change to Montane Yellow Birch-Red Spruce Forest, to Montane Spruce-Fir Forest, and finally to Subalpine Krummholz at the tree lines (Thompson and Sorenson, 2000). The Northern Green Mountains contain extensive habitat for mammals such as bear, white-tailed deer, bobcat, fisher, beaver, and red squirrel. Bird species that nest in high elevations include blackpoll warblers, Swainson's thrush, and the rare Bicknells' thrush (Thompson and Sorenson, 2000).

3.2 Geomorphic Setting

A Phase 1 Stream Geomorphic Assessment of the Mid-Winooski River watershed (which contains the Jones Brook watershed) was completed in 2007 by Bear Creek Environmental. During Phase 1, the Mid-Winooski River watershed was broken into 129 *reaches;* each reach represents a similar section of the stream based on physical attributes such as valley confinement, slope, sinuosity, bed material, dominant *bedform*, land-use, and other hydrologic characteristics. The Phase 1 assessment for the Mad River watershed was completed in 2007 by Field Geology Services. This assessment created 116 reaches throughout the watershed. A total of 13 reaches were included in this Phase 2 assessment, which equates to just over 11 river miles (see Figure 3.2). Each point in Figure 3.2 represents the downstream end of the reach.

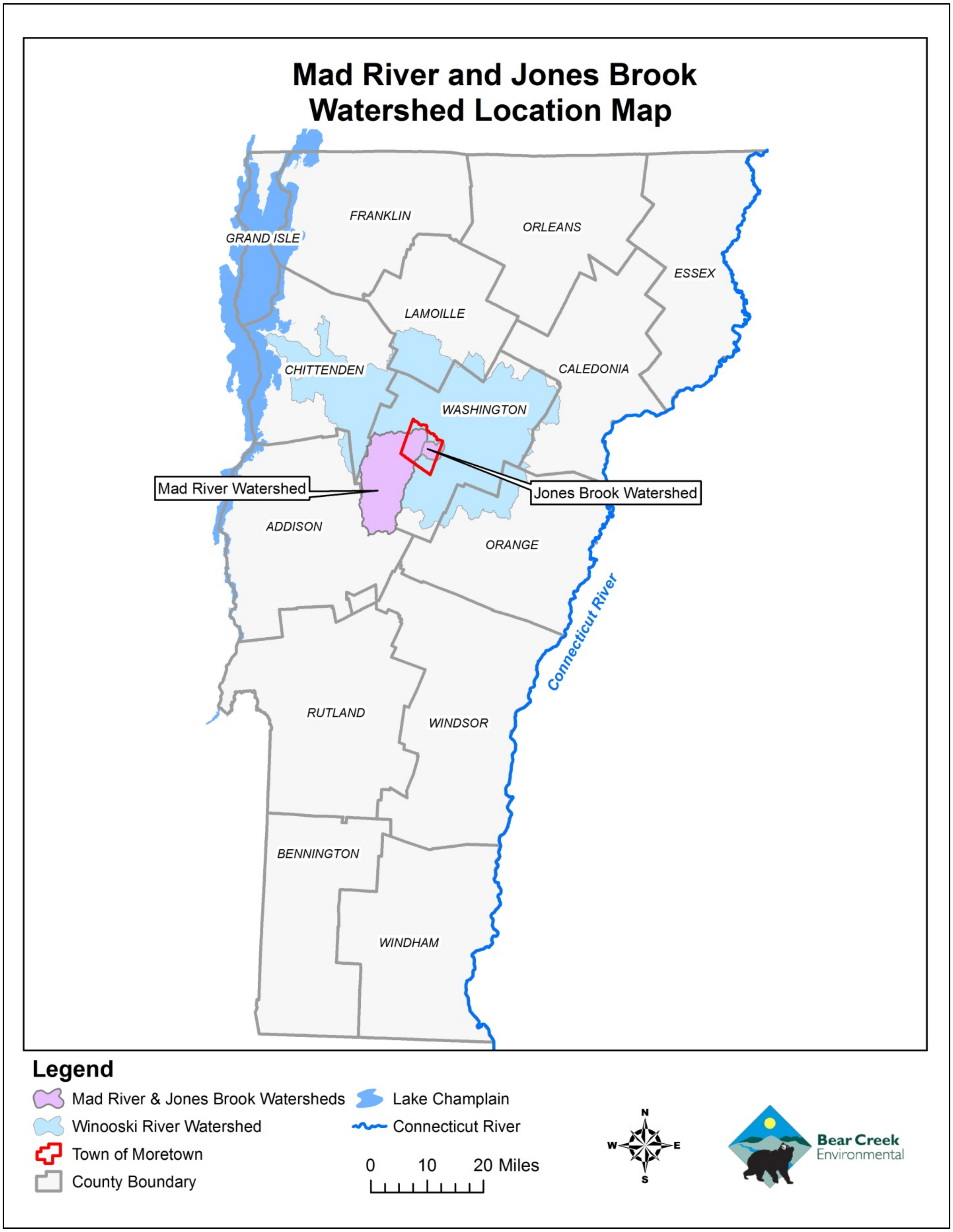
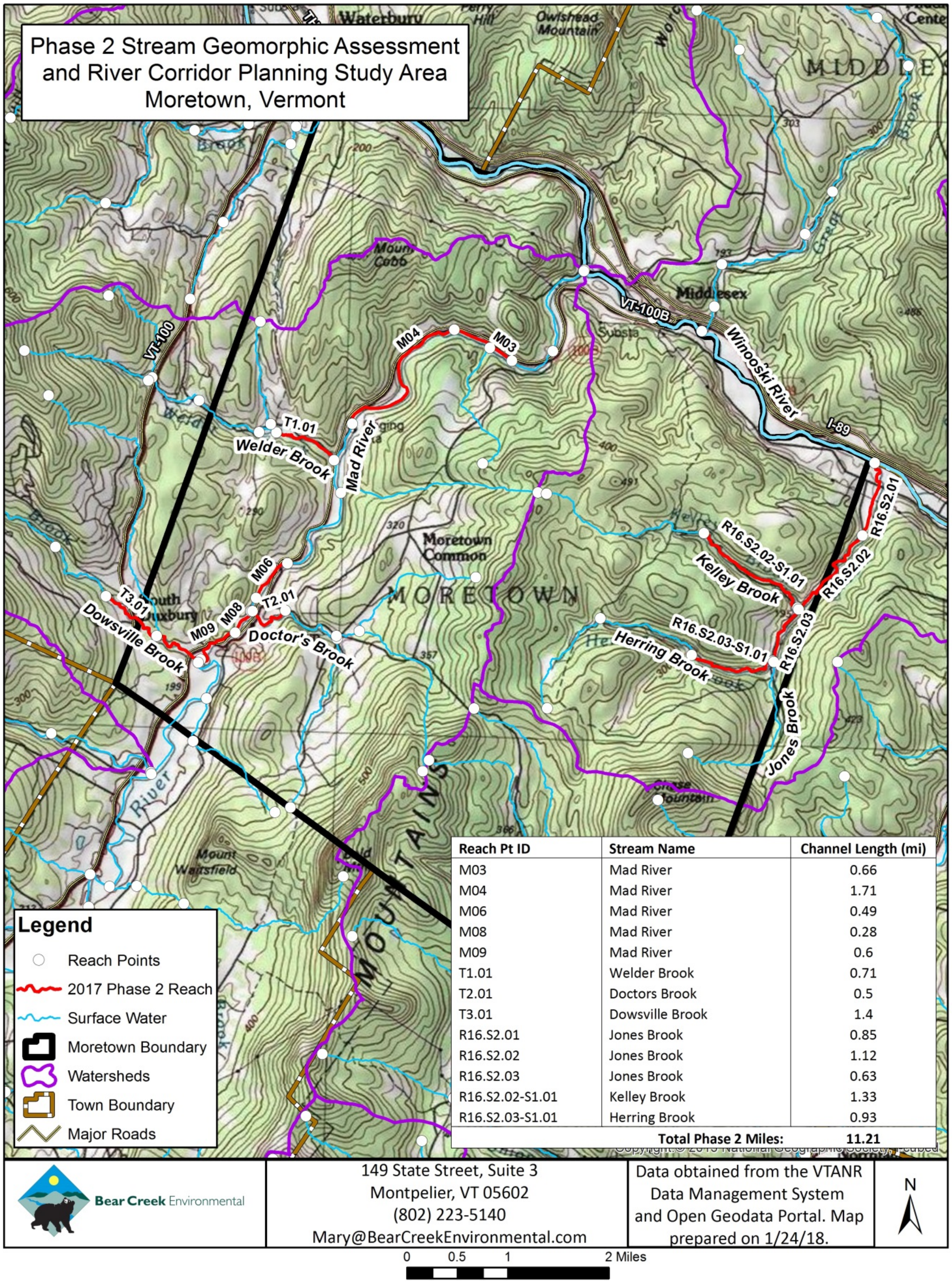


Figure 3.1. Mad River and Jones Brook watershed location.



Reach Pt ID	Stream Name	Channel Length (mi)
M03	Mad River	0.66
M04	Mad River	1.71
M06	Mad River	0.49
M08	Mad River	0.28
M09	Mad River	0.6
T1.01	Welder Brook	0.71
T2.01	Doctors Brook	0.5
T3.01	Dowsville Brook	1.4
R16.S2.01	Jones Brook	0.85
R16.S2.02	Jones Brook	1.12
R16.S2.03	Jones Brook	0.63
R16.S2.02-S1.01	Kelley Brook	1.33
R16.S2.03-S1.01	Herring Brook	0.93
	Total Phase 2 Miles:	**11.21**

Figure 3.2. Mad River and Jones Brook watershed 2017 Phase 2 study reaches.

3.3 Hydrology

In late August of 2011, Vermont was hit hard by Tropical Storm Irene (TSI). Heavy rain totaled over seven inches in areas over the course of one day. This immense downpour caused raging floodwaters to tear through Vermont's streams, devastating people and infrastructure throughout central and southern Vermont. In some areas, TSI flooding approached historic flood levels, while in other areas, the storm greatly exceeded them. Over 500 miles of state roads, in addition to over 2000 segments of municipal roads, were damaged as a result of TSI. In total, approximately 500 bridges were damaged or destroyed, as well as almost 1,000 culverts. Approximately 1,500 residences were significantly damaged or destroyed as a result of flooding, as well as state, municipal, and commercial buildings (VANR 2012a). The Winooski River and tributaries (including the Mad River) were impacted by flooding from Tropical Storm Irene, as were the communities located on their floodplains.

Within the Phase 2 study area, Tropical Storm Irene was the most damaging storm since the Flood of 1927. During Tropical Storm Irene, flood levels throughout many areas in Vermont equaled or approached the historic flood of 1927 (Vermont Agency of Natural Resources, 2012a). Many towns along the Winooski River and the Mad River experienced significant flooding and damage of property and infrastructure. Moretown was particularly hard hit, especially in its village, where development is most dense along the Mad River. Numerous homes, as well as municipal buildings, were majorly damaged by flooding during Irene. According to the Central Vermont Regional Planning Commission, "the flood waters in Moretown Village rose to the ceiling of many first floor homes and flooded the Moretown Town Office destroying nearly all Town records." Additionally, undersized culverts throughout the town sustained damage and/or washed out entirely during Irene. Road damage was widespread.

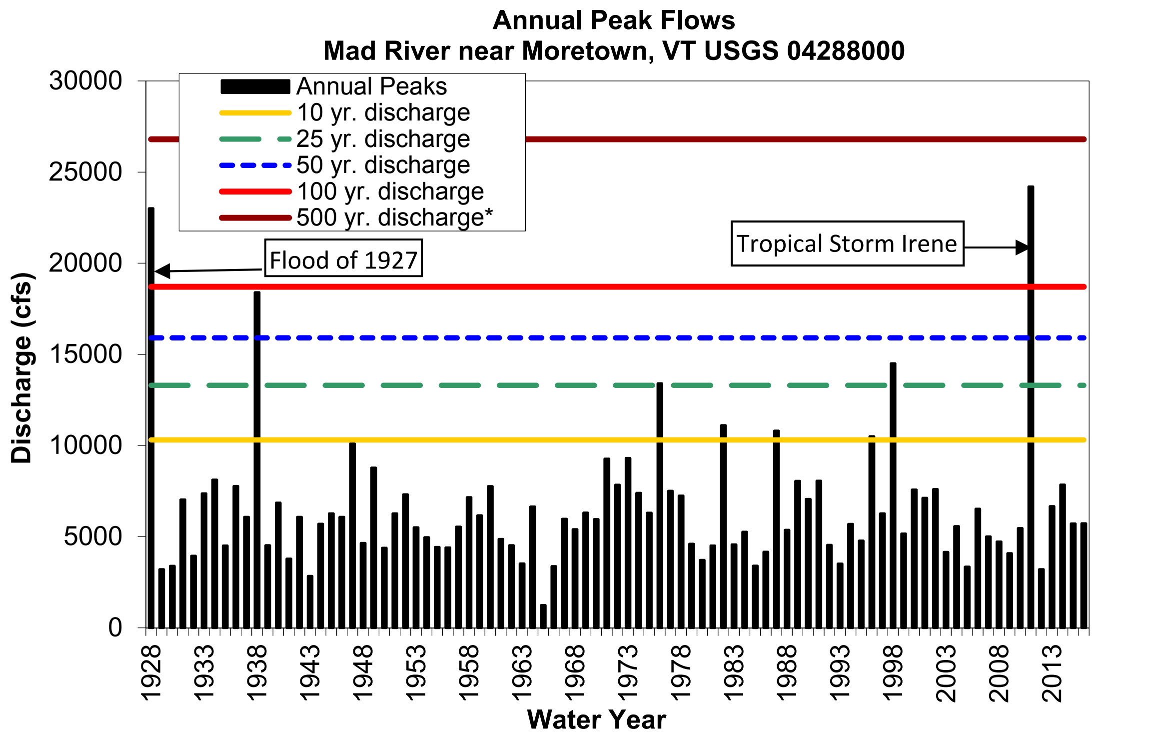
In order to better understand the flood history of the Winooski River, the Mad River, and their tributaries, long-term data from the U.S. Department of the Interior, U.S. Geological Survey (USGS), were obtained (USGS, 2017). Peak flow data from two *gaging* stations at nearby locations in the Winooski River watershed were reviewed. One station included in this analysis has a drainage area of 139 square miles and is located on the Mad River in Moretown. A second station, located on the Winooski River main stem in Montpelier (drainage area 397 square miles), was included in this analysis. Comparing annual peak flow data at these two stations for all years on record allows for an analysis of the recurrence interval of Tropical Storm Irene within the watershed.

Peak discharge records are available for the Mad River near Moretown, Vermont from 1928 through 2016 (Figure 3.3) (USGS, 2017). The highest annual peak flow on record is from Tropical Storm Irene in August 2011, which exceeded a 100 year recurrence interval. The peak flow of 24,200 cubic feet per second (cfs) on August 28, 2011 was slightly higher than the peak flow of 23,000 cfs reported for the 1927 flood.

At the Winooski River gaging station, peak discharge records are available from 1912 through 2016. The highest peak discharge available over the period of record for this station is from the Flood of 1927, which caused immense damage in central Vermont. Following the Flood of 1927, several flood control dams were installed in the Winooski River watershed. The Wrightsville Reservoir Dam on the North Branch of the Winooski River was completed in late 1935 and is located a short distance from the gaging station. The installation of this dam and another flood control dam farther upstream in East Barre has regulated the flows on the Winooski River. This regulation has resulted in lower peak flows at the gaging station in Montpelier due to increased floodwater storage capacity (Figure 3.4).

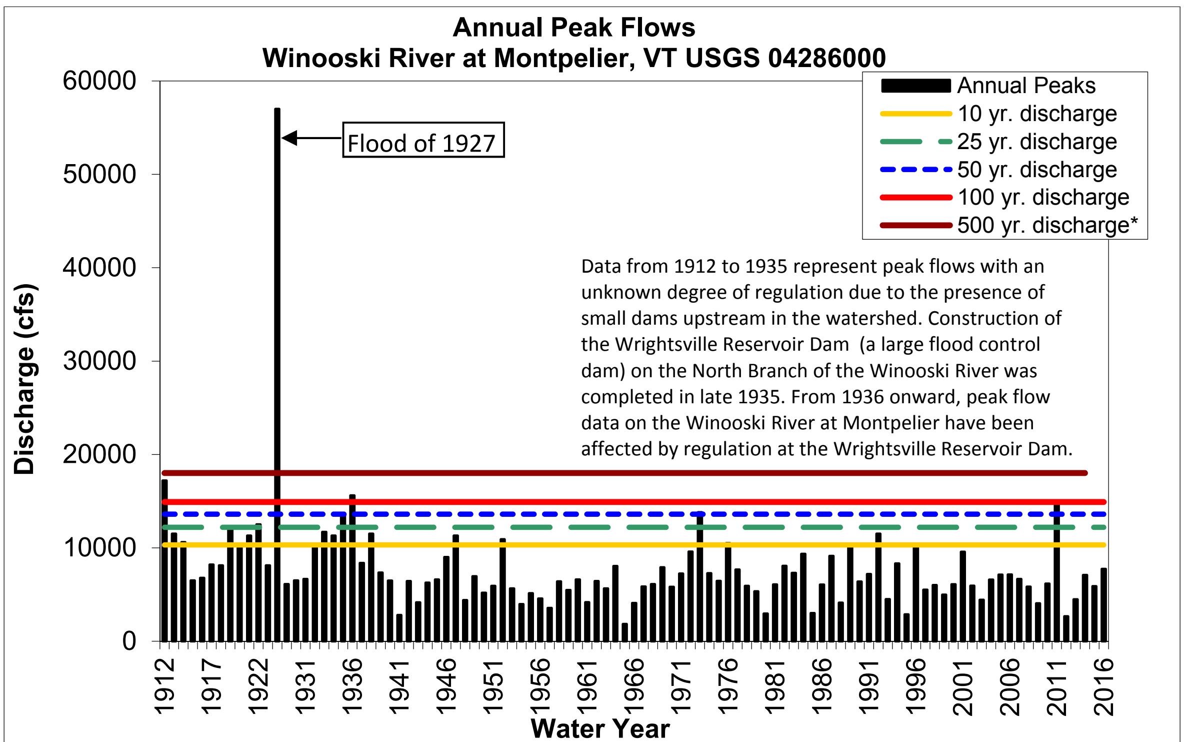
Of all the natural hazards experienced in Vermont, flooding is the most frequent, damaging, and costly. During the period of 1995-1998 alone, flood losses in Vermont totaled nearly $57 Million (Vermont Agency of Natural Resources, 2010b). The Vermont Agency of Administration (2012) states that over 733 million dollars has been estimated in funding resources for Tropical Storm Irene recovery. While some flood losses are caused by inundation (i.e. waters rise, fill, and damage low-lying structures), most flood losses in Vermont are caused by fluvial erosion.

Fluvial erosion is caused by rivers and streams, and can range from gradual bank erosion to catastrophic changes in river channel location and dimension during flood events The VANR attributes the high cost and frequency of fluvial erosion in Vermont to its geography (mountainous setting with narrow valleys and extreme climate) and past land-use practices (forest clearing) (VANR, 2010b).



*Discharges for annual exceedance probabilities from USGS report "Annual Exceedance Probabilities of Peak Discharges of 2011 at Streamgages in Vermont and Selected Streamgages in New Hampshire, Western Massachusetts, and Northeastern New York" (2013).

Figure 3.3. Annual Peak Flows for the Mad River near Moretown, Vermont.



*Discharges for annual exceedance probabilities from USGS report "Annual Exceedance Probabilities of Peak Discharges of 2011 at Streamgages in Vermont and Selected Streamgages in New Hampshire, Western Massachusetts, and Northeastern New York" (2013).

Figure 3.4. Annual Peak Flows for the Winooski River at Montpelier, Vermont.

4.0 METHODS

A summary of the Phase 1, Phase 2, and Bridge and *Culvert* methodologies is provided in the following sections.

4.1 Phase 1 Methodology

The Phase 1 assessment followed procedures specified in the Vermont Stream Geomorphic Assessment Phase 1 Handbook (Vermont Agency of Natural Resources), and used the Stream Geomorphic Assessment Tool (SGAT). SGAT is an ArcGIS extension. Phase 1, the remote sensing phase, involves the collection of data from topographic maps and aerial photographs, from existing studies, and from very limited field studies, called "windshield surveys". The Phase 1 assessment provides an overview of the general physical nature of the watershed. As part of the Phase 1 study, stream reaches are determined based on geomorphic characteristics such as: valley confinement, valley slope, geologic materials, and tributary influence.

4.2 Phase 2 Methodology

The Phase 2 assessment in Moretown followed procedures specified in the Vermont Stream Geomorphic Assessment (SGA) Phase 2 Handbook (VANR, 2009b), and used version 10.3.3 of the SGAT Geographic Information System (GIS) extension to index impacts within each reach.

The geomorphic condition for each Phase 2 reach is determined using the Rapid Geomorphic Assessment (RGA) protocol, and is based on the degree of departure of the channel from its reference stream type (VANR, 2009b). The study used the 2008 Rapid Habitat Assessment (RHA) protocol (VANR, 2008; Milone and MacBroom, Inc., 2008). The RHA is used to evaluate the physical components of a stream (channel bed, banks, and riparian vegetation) and how the physical condition of the stream affects aquatic life. The RHA results can be used to compare physical habitat condition between sites, streams, or watersheds, and they can also serve as a management tool in watershed planning.

RHA and RGA field forms were completed for the Phase 2 reaches. The appropriate RHA and RGA forms were selected based on segment characteristics and scored according to the data collected from the field assessment. A segment score and corresponding condition were determined for both the RHA and the RGA. Additionally for the RGA, major geomorphic processes were identified, the stage of channel evolution was determined, and a stream sensitivity rating was assigned.

To assure a high level of confidence in the Phase 2 SGA data, strict quality assurance/quality control (QA/QC) procedures were followed by Bear Creek Environmental. These procedures involved a thorough in-house data review, which took place during the fall and winter of 2017. The Project Team conducted the assessment according to the approved Quality Assurance procedures specified in the Phase 2 handbook. Gretchen Alexander of the State of Vermont

Watershed Management Division conducted a QA/QC review of the data collected by (BCE) for the project during January 2018.

4.3 Bridge and Culvert Methodology

Bridge assessments were conducted by BCE on all public and private crossings within the selected Phase 2 reaches. The Agency of Natural Resources Bridge and Culvert protocols (VANR, 2009a) were followed. Latitude and Longitude at each of the structures was determined using an AshTech MobileMapper 100 GPS unit. The assessment included photo documentation of the inlet, outlet, upstream, and downstream of each of the structures.

The Vermont Culvert Geomorphic Compatibility Screening Tool (Milone and MacBroom, Inc. 2008) was used to determine geomorphic compatibility for each bridge. Bridges are not typically screened for geomorphic compatibility in the VANR protocol because they are usually more robust and have less impact on stream channel function than culverts. Bridges also do not have potential to become perched above the water surface, because the bottom of the structure is natural substrate. Bridges in this study were screened using the geomorphic compatibility tool that was modified to exclude the slope parameter. Tables 1 and 2 in Appendix B explain how each bridge was scored using the Screening Tool. The compatibility rating is based on four criteria: structure width in relation to bankfull channel width, sediment continuity, river approach angle, and erosion & armoring and the ratings span the following range:

- Fully Compatible
- Mostly Compatible
- Partially Compatible
- Mostly incompatible
- Fully Incompatible

All culverts were evaluated for Aquatic Organism Passage (AOP) using the Vermont Culvert Aquatic Organism Passage Screening Tool (Milone and MacBroom, Inc., 2009). Tables 3 through 5 in Appendix B explain how each culvert was scored. The screening guide has the four following categories:

- Full AOP for all organisms
- Reduced AOP for all aquatic organisms
- No AOP for all aquatic organisms except adult salmonids
- No AOP for all aquatic organisms

4.4 Condition and Departure Analysis

4.4.1 Stream Types

Reference stream types are based on the valley type, geology and climate of a region and describe what the channel would look like in the absence of human-related changes to the channel, floodplain, valley width, and/or watershed. Table 1 shows the typical characteristics used to determine reference stream types (VANR, 2009b). Reference reach typing was based on both the Rosgen (1996) and the Montgomery and Buffington (1997) classification systems.

Table 1. Reference Stream Type

Stream Type	Confinement	Valley Slope	Bed Form
A	Narrowly Confined	Very steep > 6.5 %	Cascade
A	Confined	Very steep 4.0 - 6.5 %	Step-Pool
B	Confined or Semi- confined	Steep 3.0 – 4.0 %	Step-Pool
B	Confined, Semi- confined or Narrow	Moderate to Steep 2.0 – 3.0 %	Plane Bed
C or E	Unconfined (Narrow, Broad or Very Broad)	Moderate to Gentle <2.0 %	Riffle-Pool or Dune-Ripple
D	Unconfined (Narrow, Broad or Very Broad)	Moderate to Gentle <4.0 %	Braided Channel
F	Confined or Semi-confined	Moderate to Gentle <4.0 %	Variable

During the Phase 2 assessment, the 13 study reaches were broken into 29 segments based on detailed field observations. A segment is distinct in one or more of the following parameters: degree of floodplain encroachment or channel alteration, *grade control* occurrence (e.g. ledge), channel dimensions, channel sinuosity and slope, *riparian buffer* and corridor conditions, and degree of flow regulation. The most downstream segment within a reach is labeled "A", the second from the reach point is "B, etc. (i.e. M09-A is the most downstream segment on Reach M09).

The existing stream type is based on channel dimensions measured during the Phase 2 assessment. A stream type departure occurs when the channel dimensions deviate so far from the reference condition that the existing stream type is no longer the reference stream type. These stream type departures represent a significant change in floodplain access and stability. Watersheds that have lost attenuation or sediment storage areas due to human related constraints are generally more sensitive to erosion hazards, transport greater quantities of sediment and nutrients to receiving waters, and lack the sediment storage and distribution processes that create and maintain habitat (VANR, 2009b).

4.4.2 Geomorphic Condition

The stream condition is determined using the scores on the rapid assessment field forms, and is defined in terms of departure from the reference condition. There are four categories to describe the condition (reference, good, fair and poor). These ratings are defined below.

- Reference – no departure
- Good – minor departure
- Fair – major departure
- Poor – severe departure

Geomorphic condition is determined based on the degree (if any) of channel degradation, aggradation, widening and *planform* adjustment. Degradation is the term used to describe the process whereby the stream bed lowers in elevation through erosion, or scour, of bed material. Aggradation is a term used to describe the raising of the bed elevation through an accumulation of sediment. The planform of a channel is its shape as seen from the air. Planform change can be the result of a straightened course imposed on the river through different channel management activities, or a channel response to other *adjustment processes* such as aggradation and widening. Channel widening is a result of channel degradation or sediment build-up in the channel. In both situations the stream's energy is concentrated into both banks.

4.4.3 Habitat Condition

A second condition rating is used to evaluate reaches in a phase 2 assessment – habitat condition. Habitat condition is determined using the scores on the rapid habitat assessment (RHA) field forms. The categories for condition rating are the same as those detailed above for geomorphic condition. Scores assigned for the RHA are based on parameters that evaluate the physical characteristics of a stream. This method relates these characteristics to the habitat they provide for aquatic organisms. The RHA evaluates such characteristics as woody debris content, deposition and scour features, channel morphology, and bank and buffer vegetation.

4.4.4 Sediment Regime

Functioning floodplains play a crucial role in providing long-term stability to a river system. Natural and anthropogenic impacts may alter the equilibrium of sediment and discharge in natural stream systems and set in motion a series of morphological responses (aggradation, degradation, widening, and/or planform adjustment) as the channel tries to reestablish a dynamic equilibrium. Small to moderate changes in slope, discharge, and/or sediment supply can alter the size of transported sediment as well as the geometry of the channel; while large changes can transform reach level channel types (Ryan, 2001). Human-induced practices that have contributed to stream instability in the Mad River and Jones Brook watersheds include:

- Channelization and bank armoring
- Removal of woody riparian vegetation
- Floodplain encroachments

These anthropogenic practices have altered the balance between water and sediment discharges within the Mad River and Jones Brook watersheds. The sediment regime is the quantity, size, transport, sorting, and distribution of sediments. The sediment regime may be influenced by the proximity of sediment sources, the hydrologic characteristics of the region, and the valley, floodplain, and stream morphology (VANR, 2010a). Sediment can be supplied to the river through bank erosion, large flooding events, and stormwater inputs. Reference and existing sediment regimes were derived from the Agency of Natural Resources Data Management System according to the sediment regime criteria established by the Vermont Agency of Natural Resources (2010a).

Changes in hydrology (such as flow alteration and development of land within the riparian corridor) as well as sediment storage within the watershed have altered the reference sediment regime types for many segments within the study area. The analysis of sediment regimes at the watershed level is useful for summarizing the stressors affecting geomorphic condition of river channels. Sediment regime mapping provides a context for understanding the sediment transport and channel evolution processes.

4.4.5 Channel Evolution Model

Channel morphologic responses to anthropogenic practices contribute to channel adjustment that may further create unstable channels. All three adjustment processes, aggradation, widening and planform migration as a result of active and historic channel management are present within the Mad River and Jones Brook watersheds in the Moretown study area. The placement of state highways and town road has significantly changed river valley widths, reduced floodplain access, and altered ability of streams to meander within the study area. The floods that came through the area during TSI in August, 2011 have resulted in aggradation and planform change within some reaches.

The segment condition ratings indicate that most of the segments are actively undergoing or have historically undergone a process of major geomorphic adjustment. Many of the reaches studied in the Moretown area are undergoing a channel evolution process in response to human influences on the watershed.

The “F” stage channel evolution model (VANR, 2009b; VANR, 2004) is helpful for explaining the channel adjustment processes underway in the Mad River and Jones Brook watersheds, and is used to understand the process that occurs when a stream degrades (incises).

The common stages of the “F” channel evolution stage, as depicted in Figure 4.1 include:

- Stable (F-1) - a pre-disturbance period
- Incision (F-II) – channel degradation (*headcutting*)
- Widening (F-III) – bank failure
- Stabilizing (F-IV) – channel narrows through sediment build up and moves laterally building juvenile floodplain
- Stable (F-V) - gradual formation of a stable channel with access to its floodplain at a lower elevation

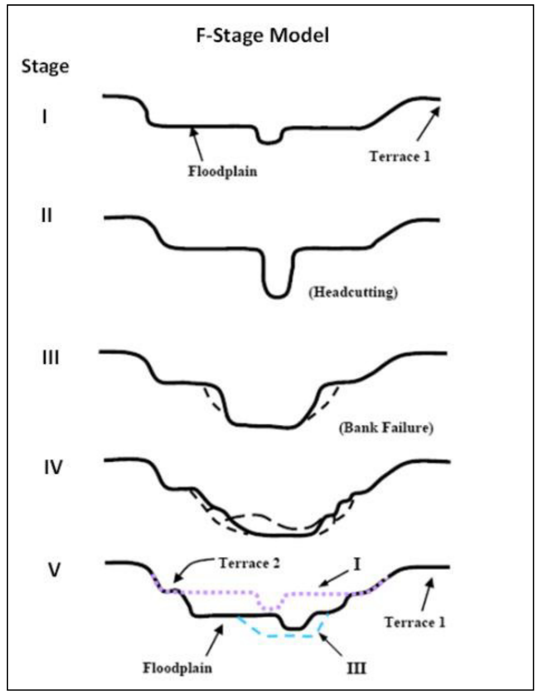


Figure 4.1 Typical channel evolution models for F-Stage (VANR, 2009b)

When stream channels are altered through straightening, it can set this evolution process into motion and cause adjustment processes to occur. The bed erosion that occurs when a meandering river is straightened in its valley is a problem that translates to other sections of the stream. Localized incision will travel upstream and into tributaries, thereby eroding sediments from otherwise stable streambeds. These bed sediments will move into and clog reaches downstream, leading to lateral scour and erosion of the stream banks. Channel evolution processes may take decades to play out. Even landowners that have maintained wooded areas along their stream and riverbanks may have experienced eroding banks as stream channel slopes adjust to match the valley slopes. It is difficult for streams to attain a new equilibrium where the placement of roads and other infrastructure has resulted in little or no valley space for the stream to access or to create a floodplain.

A second channel evolution model, known as the "D" channel evolution model is helpful for explaining channel adjustments that are driven by major aggradation. In the "D" model, channel degradation has not occurred, but rather the accumulation of sediment on the streambed causes channel widening and planform adjustment.

5.0 RESULTS

The results of the Phase 2 study in Moretown are described by reach and segment in section 5.1 below. Maps in Appendix A show the results for geomorphic condition, habitat condition, and sediment regime for each segment that was assessed. Of the 29 segments, 1 was found to be in "reference" geomorphic condition, 7 were in "good" geomorphic condition, 17 were in "fair" geomorphic condition, 2 were in "poor" geomorphic condition, and 2 were not evaluated for geomorphic condition due to not being fully assessed. The segments were not fully assessed because one is a bedrock gorge and the other was impounded by a dam at the time the field work was completed. The current geomorphic condition ratings in the assessed segments are a result of several factors. Corridor encroachments are common throughout the study area, as many roads run directly along these streams and houses exist on their banks. Development within a river corridor can cause a loss of floodplain access, changes in valley confinement, and overall geomorphic instability. Historic channel straightening is prevalent on the streams included in this assessment and has led to adjustments that are reflected in geomorphic condition scores. During Tropical Storm Irene, high stream flows likely caused changes within the study reaches. *Mass failures*, erosion, and aggradation were exacerbated by TSI in some locations, and are contributing to the unstable geomorphic condition of many assessment reaches. Also, new flood chutes likely formed, and some sections of stream took new courses through channel *avulsions*.

The rapid habitat assessment resulted in 8 segments in "good" habitat condition, 19 in "fair" habitat condition, and 2 not assessed for habitat condition. The segments that are in "good" habitat condition generally have a more natural channel planform and features such as well vegetated banks and buffers, abundant in-channel large woody debris, and a diversity of bed features including many pools, all of which provide habitat for aquatic life. Segments in "fair" habitat condition have fewer of these features and characteristics and thus provide less habitat for aquatic organisms.

As shown on the maps on pages 3 and 4 of Appendix A, many segments have experienced a departure from their reference sediment regime. Eight of 29 segments have existing sediment regimes that match their reference sediment regime; 19 segments have undergone a departure in their sediment regime, and two were not evaluated. Additionally, channel evolution stage for each Phase 2 segment was determined based on field data and observations. This information is provided by segment in section 5.1 below.

5.1 Reach/Segment Descriptions

A description of each segment is provided in this section, including major stressors and evolution processes. The segments are listed by stream location from downstream to upstream in the watershed and on each stream. Phase 2 Segment Summary Reports from the Agency of Natural Resources' Data Management System, which contain all the data for the Phase 2 steps, can be found at the following link:
https://anrweb.vt.gov/DEC/SGA/projects/phase2/reports.aspx?pid=112.

Site-specific projects have been developed to facilitate restoration, conservation, and increased *flood resiliency* within the study watersheds. Proposed project locations and impacts to each reach are provided on maps in Appendix C. Tables and photos provide greater detail about proposed projects in Appendix C. The Phase 2 stream geomorphic assessment provides a picture of the condition of the channel and the adjustment process occurring; however, it is not a comprehensive study for determining site specific actions. The Phase 2 study provides a foundation for project development, and additional work is recommended to further develop these projects.

Mad River

M03

Reach 3 on the Mad River begins at the downstream end at the Moretown No. 8 hydroelectric dam and continues upstream to Kenneth Ward Park (Appendix C, Map 1). The reach is nearly 3,500 feet in length and the river flows along Vermont Route 100B. This reach was not segmented during the assessment. The Mad River in reach M03 is backwatered due to the presence of Moretown Dam No. 8 immediately downstream. For this reason, a full Phase 2 assessment could not be completed for M03. The river flows through a semi-confined valley in this reach. Impacts include a lacking riparian buffer due to the presence of RT 100B and stormwater inputs from the road. Bank armoring is present in some areas along RT 100B. Invasive Japanese knotweed is prevalent on both banks within this reach.

Figure 5.1. M03 looking downstream – impounded.

M03 Data Summary	*NOT ASSESSED	Reference	Existing
	Confinement	Semi-Confined	Semi-Confined
Length: 3,486 ft	Stream Type	B_C	B_C
Drainage Area: 142 sq. mi.	Entrenchment Ratio	1.4 – 2.2	N/A
Evolution Stage: N/A[1]	Incision Ratio	< 1.2	N/A
Sensitivity: N/A	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Impoundment from dam downstream, lacking buffer, stormwater inputs**		

[1] N/A – Not Applicable

M04

Reach 4 on the Mad River starts downstream at Kenneth Ward Park and continues upstream to just below the bridge on Bridge Road in Moretown (Appendix C, Map 2). The river flows along VT-100B, Spillway Road, as well as farms, houses, and forest for just over 9,000 feet. The river valley within M04 is semi-confined. This reach was not segmented during the Phase 2 assessment. The majority of the reach appears to have been historically straightened due to the presence of Route 100B and adjacent residential and agricultural land uses. This straightening led to minor historic incision; widening is possibly being prevented by bank armoring. Additional impacts in M04 include lacking buffer vegetation along the west side of the river due to the presence of VT-100B, houses, and farms, and several mass failures along the eastern valley wall. Bedrock is common on the bed in this reach, which may provide some vertical stability. M04 is in **good** geomorphic condition for these reasons. The reach is in **fair** habitat condition due to lacking large woody debris and bank and buffer vegetation on one bank.

Figure 5.2. Mass failures and bedrock are common in reach M04.

M04 Data Summary		**Reference**	**Existing**
Length: 9,055 ft Drainage Area: 141 sq. mi. Evolution Stage: F-II Sensitivity: High	Confinement	Semi-Confined	Semi-Confined
	Stream Type	B_C	B_C
	Entrenchment Ratio	1.4 – 2.2	1.6
	Incision Ratio	< 1.2	1.4
	Dominant Bed Material	Cobble	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Encroachments, channel straightening, mass failures, lacking buffer**		

M06

M06 is a 2,600 foot reach on the Mad River that begins roughly 600 feet downstream of the VT-100B bridge near Dickerson Road and ends 450 feet downstream of the Fletcher Road bridge (Appendix C, Map 3). This short reach flows through a broad valley, but due to the presence of 100B in the middle of the valley, the phase 2 valley type is semi-confined. The river for almost the entirety of this reach has been historically straightened due to the road and adjacent residential/agricultural land uses. Vegetation is lacking in the riparian buffers on both banks for most of the reach, and bank vegetation is dominated by invasive Japanese knotweed. Armoring is common along the east bank of the river, especially where it flows along 100B. Due to historic channel alterations, the river has undergone major incision in this reach, which has led to a stream type departure and loss of floodplain access. For this reason, M06 is in **fair** geomorphic condition. Similarly, M06 is in **fair** habitat condition, which is due to lacking large woody debris, poor instream cover for fish, and reduced/impacted bank and buffer vegetation.

Figure 5.3. M06 flows along VT-100B and was extensively historically straightened.

M06 Data Summary		Reference	Existing
Length: 2,603 ft Drainage Area: 131 sq. mi. Evolution Stage: F-III Sensitivity: Very High	Confinement	Broad	Semi-Confined
	Stream Type	C	B_C
	Entrenchment Ratio	> 2.2	1.7
	Incision Ratio	< 1.2	1.7
	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Encroachments, channel straightening, lacking buffers, bank armoring**		

M08

Reach 8 on the Mad River flows through the village of Moretown. It is approximately 1,500 feet long, beginning just above the Fletcher Road bridge at the confluence with Doctors Brook downstream and ending upstream approximately 1,200 feet below the Route 100B bridge near Old Gulf Road (Appendix C, Map 3). The river valley in this reach is naturally very broad, but Route 100B bisects it, creating a semi-confined phase 2 valley. Adjacent lands to the west of the river in this reach are primarily forested, while lands to the east are primarily residential, with several homes along Route 100B, as well as the Moretown library, firehouse, and elementary school. Riparian buffer vegetation is lacking for the entirety of the reach on the eastern side of the river due to several lawns. Japanese knotweed is prevalent along both banks of the river in this reach. There is a high terrace along the east side of the river. Bedrock gorges exist both immediately upstream and downstream of this reach, which provides vertical stability to M08. Further vertical adjustments of the river bed are unlikely due to these upstream and downstream grade controls. M08 is in **good** geomorphic condition as a result of this stability. The reach is in **fair** habitat condition because it is lacking large woody debris, and bank and buffer vegetation are either lacking or dominated by invasive species.

Figure 5.4. Residential land use adjacent to the river in M08 has resulted in poor riparian buffer vegetation.

M08 Data Summary		**Reference**	**Existing**
	Confinement	Broad	Semi-Confined
Length: 1,492 ft	Stream Type	B_C	B_C
Drainage Area: 127 sq. mi.	Entrenchment Ratio	1.4 – 2.2	1.9
Evolution Stage: F-I	Incision Ratio	< 1.2	1.1
Sensitivity: Moderate	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Encroachments, channel straightening, lacking buffers, mass failure**		

M09
Reach 9 on the Mad River is just over 3,000 feet in length and was divided into two segments during the Phase 2 assessment to account for changes in valley width, channel dimensions, substrate size, and planform and slope.

M09-A
The downstream most segment on reach 9 is nearly 1,400 feet in length, and begins just upstream of the Moretown library and continues upstream to just above the Route 100B bridge near Old Gulf Road (Appendix C, Map 3). The Mad River flows through a bedrock gorge in segment A, and thus a full Phase 2 assessment could not be completed on this segment. It was unsafe to walk in the river within this segment; however, limited observations and impacts were recorded from the river bank. Bedrock is abundant both on the river bed and on the banks throughout this segment, providing both vertical and horizontal control for river adjustments. There is an old mill located on the south bank of the river within this segment. It was unsafe to assess the Route 100B bridge within this segment, but it was noted as being in poor condition. Administrative judgement data were collected for the segment, placing it in **good** geomorphic condition.

Figure 5.5. The Mad River flows through a bedrock gorge in M09-A.

M09-A Data Summary	*NOT ASSESSED	Reference	Existing
Length: 1,355 ft Drainage Area: 126 sq. mi. Evolution Stage: N/A Sensitivity: N/A	Confinement	Narrowly Confined	Narrowly Confined
	Stream Type	G_C	G_C
	Entrenchment Ratio	< 1.4	N/A
	Incision Ratio	< 1.2	N/A
	Dominant Bed Material	Bedrock	Bedrock
	Dominant Bedform	Cascade	Cascade
Major Stressors:	**None identified**		

M09-B

The upstream segment on reach M09 of the Mad River is roughly 1,800 feet in length, beginning just above the Route 100B bridge near Old Gulf Road and ending immediately upstream of the confluence of Dowsville Brook with the Mad River (Appendix C, Map 3). The river flows through a broad valley in this segment with adjacent agricultural and residential lands. This section of the Mad River is moderately sinuous and has several large aggradational features. Additionally, the river is exhibiting planform change in this segment via a flood chute and an impending *neck cutoff*. There is major erosion on both banks throughout the reach, especially on the outside of meander bends. Both streambanks are blanketed in Japanese knotweed. Major historic incision has occurred in this segment, which has resulted in a loss of floodplain access and a stream type departure. The river appears to be building a juvenile floodplain at a lower elevation. Due to these adjustments, M09-B was placed in **fair** geomorphic condition. The morphological characteristics of the river in this segment, as well as impacted banks and buffers, led to its placement in **fair** habitat condition.

Figure 5.6. Overly wide channel with abundant aggradation in M09-B.

M09-B Data Summary		Reference	Existing
Length: 1,795 ft Drainage Area: 126 sq. mi. Evolution Stage: F-IV Sensitivity: Extreme	Confinement	Broad	Broad
	Stream Type	C	F
	Entrenchment Ratio	> 2.2	1.3
	Incision Ratio	< 1.2	1.8
	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Bank erosion, channel straightening, pending neck cutoff, channel encroachment, lacking buffers**		

Welder Brook

Welder Brook is a tributary to the Mad River that enters the river in reach M05 near the intersection of Route 100B and Stevens Brook Road.

T1.01

Reach 1 on Welder Brook was split into two segments during the Phase 2 assessment to account for changes in planform and slope, banks and buffers, valley width, grade controls, and substrate size.

T1.01-A

The downstream segment on reach 1 of Welder Brook begins at the confluence with the Mad River and continues upstream for roughly 2,500 feet to behind 445 Stevens Brook Road (Appendix C, Map 4). The segment is characterized by a step-pool bedform and abundant bedrock grade controls. Impacts within this segment are minimal and mostly relate to the presence of Stevens Brook Road along the north side of the stream channel. There are short sections of the brook that appear to have been straightened along the road, but for the most part, channel planform is natural. The abundant bedrock on the streambed in T1.01-A provides stability to the brook, which has not undergone incision or widening. T1.01-A is in **good** geomorphic condition for this stability and lack of impacts. Similarly, the segment is in **good** habitat condition, as it has a diversity of bed features, good instream cover, and mostly well forested buffers.

Figure 5.7. Bedrock grade controls are abundant in T1.01-A.

T1.01-A Data Summary		**Reference**	**Existing**
Length: 2,487 ft Drainage Area: 4.2 sq. mi. Evolution Stage: F-I Sensitivity: Moderate	Confinement	Broad	Broad
	Stream Type	B	B
	Entrenchment Ratio	1.4 – 2.2	1.4
	Incision Ratio	< 1.2	1.0
	Dominant Bed Material	Cobble	Cobble
	Dominant Bedform	Step-Pool	Step-Pool
Major Stressors:	**Bank erosion, road encroachment, stormwater inputs, lacking buffer**		

T1.01-B

Segment B on reach one of Welder Brook is just over 1,200 feet in length and flows through a very broad valley (Appendix C, Map 4). This segment is within a large wetland complex and the brook has a low gradient, sinuous channel. The riparian buffers are well vegetated with shrub/sapling and herbaceous vegetation. There are multiple side channels and flood chutes throughout this segment where water spreads out as flows rise. Bank erosion is common, especially on outside meander bends, as are steep riffles. The brook has not incised in this segment, and human alteration is minimal. The planform is natural and floodplain connectivity is excellent. For these reasons, T1.01-B is in **good** geomorphic condition. The segment is also in **good** habitat condition, with its abundant large woody debris, diverse bed features, and well vegetated banks and buffers.

Figure 5.8. T1.01-B has a narrow, sinuous wetland channel.

T1.01-B Data Summary		**Reference**	**Existing**
Length: 1,242 ft Drainage Area: 4.2 sq. mi. Evolution Stage: F-I Sensitivity: High	Confinement	Very Broad	Very Broad
	Stream Type	C	C
	Entrenchment Ratio	> 2.2	9.3
	Incision Ratio	< 1.2	1.1
	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Bank erosion**		

Doctors Brook

Doctors Brook flows into the Mad River in Moretown village between the Moretown General Store and the firehouse.

T2.01

Reach one on Doctors Brook begins at the confluence with the Mad River and continues upstream where it ends in the woods adjacent to Moretown Mountain Road near the Green Mountain Power substation. It was separated into two segments during the Phase 2 assessment to account for changes in channel planform and slope, channel alterations, and banks and buffers.

T2.01-A

The lower segment on reach one of Doctors Brook is roughly 1,200 feet in length, ending just upstream of a private bridge (Appendix C, Map 3). The entirety of this segment appears to have been historically straightened due to the presence of houses and roads along its banks. This extensive straightening has led to major historic channel incision, a stream type departure, and a loss of floodplain access. Abundant bank armoring is preventing channel widening for much of this segment; however, areas that are not armored have severely eroding banks. Riparian buffers are lacking on both banks for most of the segment. For the aforementioned reasons, T1.01-A was placed in **poor** geomorphic condition. The segment is in **fair** habitat condition as a result of lacking large woody debris, altered channel planform, and impacted banks and buffers.

Figure 5.9. T2.01-A has been extensively straightened and riprapped.

<table>
<tr><th>T2.01-A Data Summary</th><th></th><th>Reference</th><th>Existing</th></tr>
<tr><td rowspan="6">Length: 1,249 ft
Drainage Area: 4.6 sq. mi.
Evolution Stage: F-II
Sensitivity: Extreme</td><td>Confinement</td><td>Very Broad</td><td>Very Broad</td></tr>
<tr><td>Stream Type</td><td>C</td><td>F</td></tr>
<tr><td>Entrenchment Ratio</td><td>> 2.2</td><td>1.2</td></tr>
<tr><td>Incision Ratio</td><td>< 1.2</td><td>2.0</td></tr>
<tr><td>Dominant Bed Material</td><td>Cobble</td><td>Cobble</td></tr>
<tr><td>Dominant Bedform</td><td>Riffle-Pool</td><td>Riffle-Pool</td></tr>
<tr><td>Major Stressors:</td><td colspan="3">Channel straightening, bank armoring, bank erosion, encroachments, lacking buffers</td></tr>
</table>

T2.01-B

The upper segment on reach one of Doctors Brook is nearly 1,400 feet in length and flows through a forested, very broad valley (Appendix C, Map 3). The brook has a natural planform in this segment and minimal human alteration. A small section of historic channel straightening was observed at the downstream end of the segment, and another small area of channel alteration exists in the vicinity of a stream ford. Severe bank erosion was noted in this segment, especially on outside meander bends. Three mass failures were documented, the largest of which is located on the western bank of the brook toward the downstream end of the segment and is underlain by clay and sand. BCE observed one channel avulsion toward the upstream end of the segment where the brook appears to have formed a new primary flow path fairly recently. Severe historic incision was noted in this segment, which likely stems from the extensive historic channel alteration downstream in segment A. A stream type departure has occurred in T2.01-B, along with some loss of floodplain access. For these reasons, T2.01-B was placed in **fair** geomorphic condition. Despite channel adjustments and instability, there is abundant large woody debris and abundant pool features in this segment, as well as well forested banks and buffers. T2.01-B received a ranking of **good** for habitat condition.

Figure 5.10. Channel avulsion in T2.01-B.

T2.01-B Data Summary		Reference	Existing
Length: 1,372 ft Drainage Area: 4.6 sq. mi. Evolution Stage: F-III Sensitivity: High	Confinement	Very Broad	Very Broad
	Stream Type	C	B
	Entrenchment Ratio	> 2.2	1.6
	Incision Ratio	< 1.2	2.1
	Dominant Bed Material	Cobble	Cobble
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Bank erosion, mass failures**		

Dowsville Brook

Dowsville Brook is a tributary that flows into the Mad River in reach M09. The brook flows from Duxbury into Moretown, entering the Mad River near the intersection of Route 100 and Route 100B.

T3.01

Reach one on Dowsville Brook begins upstream in the woods west of the cul-de-sac on Clark Road and ends at the confluence with the Mad River. The reach was split into three segments during assessment to account for changes in valley width, channel planform, corridor encroachments, and surrounding land uses.

T3.01-A

The downstream-most segment on reach one of Dowsville Brook is nearly 1,400 feet in length, extending from roughly 500 feet upstream of the Route 100B bridge downstream to the confluence with the Mad River (Appendix C, Map 5). Adjacent lands to this segment of the brook are primarily agricultural. Because of this, riparian buffer vegetation is lacking on both sides of the brook for much of the segment. The majority of T3.01-A appears to have been historically straightened due to the presence of the Route 100B crossing and surrounding agricultural lands. This historic straightening has led to channel incision, widening, and a departure from reference stream type. Due to these impacts and adjustments, T3.01-A is in **fair** geomorphic condition. Channel alterations and reduced bank and buffer vegetation led to the placement of T3.01-A in in **fair** habitat condition.

Figure 5.11. Straightened channel in T3.01-A.

T3.01-A Data Summary		**Reference**	**Existing**
Length: 1,383 ft Drainage Area: 9.1 sq. mi. Evolution Stage: F-III Sensitivity: Very High	Confinement	Very Broad	Very Broad
	Stream Type	D	C
	Entrenchment Ratio	> 2.2	2.7
	Incision Ratio	< 1.2	1.9
	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Channel straightening, bank erosion, bank armoring, lacking buffers**		

T3.01-B

Segment B on reach one of Dowsville Brook is nearly 3,600 feet in length, beginning about 500 feet above the Route 100B bridge and ending upstream about 500 feet below the Route 100 bridge (Appendix C, Map 5). The brook flows through forested land in this segment and has minimal channel alteration. T3.01-B has undergone major aggradation and channel widening, leading to planform change. The channel is braided at low flows at some locations in this segment, but there are side channels and flood chutes throughout the segment, creating braiding at higher flows as well. Bank erosion is common on the outside of meander bends. Debris jams are abundant and are also contributing to planform change within T3.01-B. This segment is in **fair** geomorphic condition due to the major adjustments it is undergoing. The brook has abundant large woody debris and pools, as well as well forested banks and buffers. T3.01-B is in **good** habitat condition.

Figure 5.12. Aggradation and low flow braiding in T3.01-B.

T3.01-B Data Summary		Reference	Existing
Length: 3,557 ft Drainage Area: 9.1 sq. mi. Evolution Stage: DIId Sensitivity: Extreme	Confinement	Very Broad	Very Broad
	Stream Type	D	D
	Entrenchment Ratio	> 2.2	2.5
	Incision Ratio	< 1.2	1.0
	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Bank erosion, mass failure**		

T3.01-C

The upstream most segment on reach one of Dowsville Brook is characterized as having a higher slope than the downstream segments. This nearly 2,500 foot segment is located in Duxbury and flows through forested and residential land from just downstream of the Route 100 bridge upstream to near the cul-de-sac on Clark Road (Appendix C, Map 5). Historic and recent channel alterations were observed during the Phase 2 assessment, including channel straightening, dredging, windrowing, and berms. The uppermost portion of this segment has a higher slope than the rest of the segment, which is flatter and has large depositional features. Large flood chutes are present throughout the segment, contributing to planform adjustment. Sections of the brook appear to have been historically straightened behind several of the homes on Clark Road. Historic and recent berms, windrowing, and dredging were observed in the lower half of the segment above the Route 100 bridge. Major incision has occurred in this segment, though it has not led to a stream type departure. T3.01-C is in **fair** geomorphic condition and **fair** habitat condition due to the aforementioned alterations and adjustments, as well as impacted riparian buffers.

Figure 5.13. T3.01-C at cross section location.

T3.01-C Data Summary		Reference	Existing
Length: 2,476 ft Drainage Area: 9.1 sq. mi. Evolution Stage: F-III Sensitivity: Very High	Confinement	Very Broad	Very Broad
	Stream Type	C_b	C_b
	Entrenchment Ratio	> 2.2	2.7
	Incision Ratio	< 1.2	2.2
	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Channel straightening, windrowing, encroachments, development, bank erosion, dredging**		

Jones Brook

Jones Brook is a tributary to the Winooski River that flows through the towns of Moretown and Berlin. Three reaches on Jones Brook were included in this Phase 2 assessment.

R16.S2.01

Reach one on Jones Brook flows adjacent to agricultural lands near the confluence with the Winooski River. The reach was split into three segments during the assessment to account for changes in valley width, channel planform and slope, and depositional features.

R16.S2.01-A

The downstream most segment on reach one of Jones Brook is approximately 2,300 feet in length, beginning roughly 700 feet above the Three Mile Bridge Road bridge at the upstream end and flowing downstream to the confluence with the Winooski River (Appendix C, Map 6). R16.S2.01-A flows through a very broad valley along several corn fields. Most of the segment appears to have been historically straightened due to the surrounding land use. Historic incision occurred within this segment and channel widening is actively occurring. Riprap is abundant along both banks, but bank erosion is occurring where riprap is not present. Some planform change was noted in the form of flood chutes. Lateral adjustments are being limited by bank armoring. R16.S2.01-A is in **fair** geomorphic condition for these reasons. The brook is also in **fair** habitat condition in this segment due to its altered planform, as well as lacking bank and buffer vegetation. Japanese knotweed is prevalent along both banks.

Figure 5.14. Large bar and riprapped bank in R16.S2.01-A.

R16.S2.01-A Data Summary		Reference	Existing
Length: 2,313 ft Drainage Area: 10.1 sq.mi. Evolution Stage: F-III Sensitivity: Very High	Confinement	Very Broad	Very Broad
	Stream Type	C	C
	Entrenchment Ratio	> 2.2	7.6
	Incision Ratio	< 1.2	2.0
	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Channel straightening, bank armoring, bank erosion, lacking buffers**		

R16.S2.01-B

Segment B on reach one of Jones Brook is roughly 1,200 feet in length (Appendix C, Map 6). This segment differs from segments A and C primarily in channel planform and dimensions. R16.S2.01-B is characterized by abundant large depositional features, creating an extremely wide channel and low flow braiding conditions. There are several flood chutes and side channels that appear to be wetted at various flow conditions (including low flow). There are few human impacts to the brook within this segment, which include one stream ford and a very short section of minor windrowing just upstream of the ford. There is a major gully coming off of the east valley wall within this segment that may contribute large amounts of fine sediment to the brook. The source of the gully is unknown though it appears to originate in a clearing upslope and may be related to logging activities. The brook is part of a naturally very dynamic system. R16.S2.01-B is in **fair** geomorphic condition as a result of its abundant adjustments. Similarly, the brook is in **fair** habitat condition within this segment due to lacking instream cover and its hydrologic conditions that create a shallow channel without a diversity of bed features.

Figure 5.15. There is major aggradation and braiding in R16.S2.01-B.

R16.S2.01-B Data Summary		**Reference**	**Existing**
Length: 1,230 ft Drainage Area: 10.1 sq.mi. Evolution Stage: D-IId Sensitivity: Extreme	Confinement	Very Broad	Very Broad
	Stream Type	D	D
	Entrenchment Ratio	> 2.2	1.8
	Incision Ratio	< 1.2	1.2
	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Braided	Braided
Major Stressors:	**Bank erosion, gully**		

R16.S2.01-C

The upstream most segment on reach one of Jones Brook is just over 900 feet in length and flows through a narrower, steeper valley than the two downstream segments (Appendix C, Map 6). The brook is characterized by a naturally straight channel with large substrate. The brook has undergone historic incision and recent channel widening, which has led to a stream type departure. Large bars are present at the downstream end of the segment. It appears that the brook has been minimally altered, as it flows through the woods away from development along Jones Brook Road. R16.S2.01-C is in **fair** geomorphic condition as a result of historic and recent channel adjustments. The brook is also in **fair** habitat condition for many reasons, including lacking pool features, unstable banks, and a wide channel with mostly shallow water.

Figure 5.16. Wide, straight channel in R16.S2.01-C.

R16.S2.01-C Data Summary		**Reference**	**Existing**
	Confinement	Broad	Broad
Length: 945 ft	Stream Type	C	B_C
Drainage Area: 10.1 sq.mi.	Entrenchment Ratio	> 2.2	1.6
Evolution Stage: F-III	Incision Ratio	< 1.2	1.8
Sensitivity: High	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Bank erosion, mass failures**		

R16.S2.02

Reach two on Jones Brook begins upstream at the confluence with Kelley Brook in Moretown and ends downstream near 592 Jones Brook Road in Berlin. The reach was divided into five segments during the assessment to account for changes in valley width and bank/buffer vegetation.

R16.S2.02-A

The downstream most segment on reach two of Jones Brook flows through a narrow valley in the Town of Berlin. The downstream half of the segment flows through the woods, while the upstream half flows through a residential area along the west bank of the brook (Appendix C, Map 6). Aggradation is a major process that is currently occurring within R16.S2.02-A. Numerous large bars are present throughout the segment causing the formation of steep riffles and channel widening. Although moderate historic incision has occurred within this segment, floodplain access is still mostly intact. Riparian buffers are lacking in the vicinity of two houses along the western bank of Jones Brook. Bank erosion is common along both banks within this segment, which provides further evidence that channel widening is occurring, and four mass failures are present. R16.S2.02-A is in **fair** geomorphic condition as a result of historic and active channel adjustments. This segment is also in **fair** habitat condition due to such factors as lacking instream cover, reduced bank and buffer vegetation, and lacking pool features.

Figure 5.17. Aggradation is a major process currently occurring within R16.S2.02-A.

R16.S2.02-A Data Summary		Reference	Existing
Length: 2,509 ft Drainage Area: 9.5 sq. mi. Evolution Stage: F-III Sensitivity: Very High	Confinement	Narrow	Narrow
	Stream Type	C	C
	Entrenchment Ratio	> 2.2	2.2
	Incision Ratio	< 1.2	1.5
	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Bank erosion, mass failures, lacking buffers, gully**		

R16.S2.02-B

Segment B on reach two of Jones Brook is a short segment – only roughly 900 feet in length and is located in Berlin. The brook flows through a slightly wider valley in this segment than downstream and has more channel alteration due to the presence of residences on both sides of the brook (Appendix C, Map 6). Much of the segment appears to have been historically straightened up against the eastern valley wall due to residential land use on the west. Buffer vegetation is lacking for most of the segment on the western side of the brook, but also for a small section on the eastern side. The historic straightening in this segment appears to have led to major historic incision, resulting in a stream type departure and loss of floodplain access. Major aggradation has also occurred within this segment, as evidenced by several large bar features. For these reasons, R16.S2.02-B is in **fair** geomorphic condition. The segment is also in **fair** habitat condition as a result of lacking instream cover and pool habitat, channel adjustments that have created a wide, shallow channel, and lacking bank and buffer vegetation.

Figure 5.18. Wide, depositional channel in R16.S2.02-B.

R16.S2.02-B Data Summary		Reference	Existing
Length: 880 ft Drainage Area: 9.5 sq. mi. Evolution Stage: F-III Sensitivity: Very High	Confinement	Broad	Broad
	Stream Type	C	B_C
	Entrenchment Ratio	> 2.2	1.5
	Incision Ratio	< 1.2	2.5
	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Channel straightening, bank erosion, encroachments, lacking buffer, dredging**		

R16.S2.02-C

Segment C on reach two of Jones Brook flows through a narrower valley than the adjacent segments. It is roughly 1,200 feet in length and flows mostly through the woods along Jones Brook Road (Appendix C, Map 7). The lower end of the segment is in Berlin, while the upstream end is in Moretown. Very few channel alterations were observed within this segment, which has a mostly natural planform. Moderate historic incision was noted at the cross section for R16. S2.02-C, as well as minor widening. A few areas of bank erosion were noted in this segment, particularly on the eastern bank. Due to historic and recent channel adjustments, this segment was placed in **fair** geomorphic condition. R16.S2.02-C lacked large woody debris at the time of the assessment. Hydrologic characteristics and impacted bank and buffer vegetation on one side of the channel also contributed to the segment being placed in **fair** habitat condition.

Figure 5.19. R16.S2.02-C has a narrower valley and is naturally more entrenched than downstream segments.

R16.S2.02-C Data Summary		**Reference**	**Existing**
Length: 1,240 ft Drainage Area: 9.5 sq. mi. Evolution Stage: F-III Sensitivity: High	Confinement	Semi-Confined	Semi-Confined
	Stream Type	B_C	B_C
	Entrenchment Ratio	1.4 – 2.2	1.6
	Incision Ratio	< 1.2	1.6
	Dominant Bed Material	Cobble	Cobble
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Bank erosion, lacking buffer**		

R16.S2.02-D

Segment D on R16.S2.02 is very short, only 584 feet in length. This segment flows through the woods and has a large bedrock grade control at its downstream end (Appendix C, Map 7). This grade control provides vertical stability to the channel within R16.S2.02-D, which has prevented major channel incision. Jones Brook upstream of the bedrock grade control appears to be undergoing minor channel widening with extensive bank erosion along the west bank. Overall, R16.S2.02-D was reported to be in **good** geomorphic condition due to only minor channel adjustments. Similarly, segment D was placed in **good** habitat condition, as it has good instream cover, a diversity of bed features, and mostly well vegetated banks and buffers.

Figure 5.20. Large bedrock grade control at the downstream end of R16.S2.02-D.

R16.S2.02-D Data Summary		**Reference**	**Existing**
Length: 584 ft Drainage Area: 9.5 sq. mi. Evolution Stage: F-III Sensitivity: Moderate	Confinement	Semi-Confined	Semi-Confined
	Stream Type	C	C
	Entrenchment Ratio	> 2.2	2.3
	Incision Ratio	< 1.2	1.3
	Dominant Bed Material	Gravel	Cobble
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Bank erosion, gully**		

R16S2.02-E

The upstream most segment on reach two of Jones Brook is nearly 700 feet in length, and flows through primarily residential land along Jones Brook Road (Appendix C, Map 7). This land use appears to have resulted in historic straightening for the entirety of this segment. Severe historic incision has occurred within R16.S2.02-E, causing a stream type departure and loss of floodplain access. Some channel widening is occurring, though it is limited in some locations due to riprap. Riparian buffer vegetation is lacking along the western side of Jones Brook for the whole segment. R16.S2.02-E is in **fair** geomorphic condition due to extensive historic channel alteration and severe historic incision. Large woody debris, bed features, and bank and buffer vegetation are lacking, which resulted in the placement of the segment in **fair** habitat condition.

Figure 5.21. Jones Brook has a straight and severely incised channel in R16.S2.02-E.

R16.S2.02-E Data Summary		**Reference**	**Existing**
Length: 695 ft Drainage Area: 9.5 sq. mi. Evolution Stage: F-III Sensitivity: Extreme	Confinement	Broad	Broad
	Stream Type	C	F
	Entrenchment Ratio	> 2.2	1.2
	Incision Ratio	< 1.2	2.7
	Dominant Bed Material	Gravel	Cobble
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Channel straightening, encroachment, bank erosion, bank armoring, lacking buffer**		

R16.S2.03

Reach three on Jones Brook spans the area between the confluence of Kelley Brook and the confluence of Herring Brook. This reach was divided into three segments during the assessment to account for changes in corridor encroachment and channel planform. Jones Brook flows along Jones Brook Road and development along the road for all of reach three.

R16.S2.03-A

The downstream most segment on reach three of Jones Brook is just over 800 feet in length, beginning at the confluence with Kelley Brook downstream and ending upstream where the brook flows away from Jones Brook Road (Appendix C, Map 7). This segment has a very broad valley by reference; however, the valley is bisected by Jones Brook Road, which functionally narrows the valley. All of segment A appears to have been historically straightened due to the placement of Jones Brook Road in the western corridor and a house on the east of the brook. Despite this historic straightening, minimal channel incision has occurred within R16.S2.03-A. Bedrock grade controls exist both upstream and downstream of this segment, which may contribute to the vertical stability within the segment. Similarly, aggradation, widening, and planform change are minimal in this segment. A geomorphic condition of **good** was given to this segment for this lack of channel adjustments and the segment's relative stability. R16.S2.03-A ranked **fair** for habitat condition for the brook's lack of large woody debris, its altered planform, and lacking bank and buffer vegetation.

Figure 5.22. R16.S2.02-A looking downstream at the cross section location.

R16.S2.03-A Data Summary		Reference	Existing
Length: 804 ft Drainage Area: 6.5 sq. mi. Evolution Stage: F-II Sensitivity: High	Confinement	Very Broad	Narrow
	Stream Type	C	C
	Entrenchment Ratio	> 2.2	2.7
	Incision Ratio	< 1.2	1.3
	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Channel straightening, encroachment, lacking buffers, bank erosion**		

R16.S2.03-B

The second segment on reach three of Jones Brook is characterized by major channel encroachment by Jones Brook Road. This very short segment (just over 400 feet in length) flows directly along the road (Appendix C, Map 7). The brook has been straightened along the eastern valley wall for nearly the entire segment and is currently trapped between the road and valley wall. There is a major human caused change in valley width in this segment due to the presence of Jones Brook Road. Extensive bank armoring is present along the road. The road encroachment creates a human elevated floodplain and a high incision ratio, and has resulted in loss of floodplain access and a stream type departure. Lateral channel adjustments are being prevented by the bank armoring present on the west side of the channel and the valley wall immediately on the east. R16.S2.03-B is in **fair** geomorphic condition for these reasons. The straightened channel in this segment lacks large woody debris, pool features, and bank and buffer vegetation on one side. For these reasons, R16.S2.03-B is also in **fair** habitat condition.

Figure 5.23. R16.S2.03-B has been extensively straightened along Jones Brook Road.

R16.S2.03-B Data Summary		**Reference**	**Existing**
Length: 416 ft Drainage Area: 6.5 sq. mi. Evolution Stage: F-III Sensitivity: Very High	Confinement	Very Broad	Semi-Confined
	Stream Type	C	F
	Entrenchment Ratio	> 2.2	1.3
	Incision Ratio	< 1.2	2.1
	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Channel straightening, encroachment, lacking buffer, bank armoring**		

R16.S2.03-C

The upstream most segment on reach three of Jones Brook is the longest, at 2,100 feet. Jones Brook appears to have been historically straightened for the entire length of this segment due to several houses along Jones Brook Road (Appendix C, Map 7). Five ledge grade controls are present in the middle and at the downstream end of this segment, which afford the channel some vertical stability. Moderate historic incision has occurred within R16.S2.03-C likely as a result of channel alteration. Widening is currently occurring as evidenced through abundant bank erosion. Riparian buffer vegetation is lacking for about half of the segment. R16.S2.03-C is in **fair** geomorphic condition and **fair** habitat condition.

Figure 5.24. Straight channel in R16.S2.03-C.

R16.S2.03-C Data Summary		**Reference**	**Existing**
Length: 2,099 ft Drainage Area: 6.5 sq. mi. Evolution Stage: F-III Sensitivity: Very High	Confinement	Very Broad	Broad
	Stream Type	C	C
	Entrenchment Ratio	> 2.2	2.3
	Incision Ratio	< 1.2	1.7
	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Channel straightening, encroachment, lacking buffers, bank erosion**		

Kelley Brook

Kelley Brook is a tributary to Jones Brook that flows from west to east in Moretown and enters Jones Brook in reach R16.S2.02.

R16.S2.02-S1.01

Reach one on Kelley Brook was split into two segments during assessment due to changes in channel dimensions, corridor encroachments, and valley width.

R16.S2.02-S1.01-A

The downstream segment on reach one of Kelley Brook is characterized by a broad valley and moderate channel slope. Bedrock grade controls are common throughout this segment. Ward Brook Road is a corridor encroachment for nearly the entire length of the segment (Appendix C, Map 8). Almost all of R16.S2.02-S1.01-A has been historically straightened due to the placement of Ward Brook Road and houses along it. Additionally, there is extensive bank armoring, especially in areas where the brook is directly adjacent to the road. Channel straightening and bank armoring have led the brook to undergo major historic incision in this segment, resulting in a loss of floodplain access and a stream type departure. Channel widening is prevented by bank armoring on one side of the channel and the location of the valley wall on the other side for much of the segment; however, bank erosion is common where armoring is not present. Segment A was placed in **fair** geomorphic condition for these reasons. Habitat condition is also **fair** due to the altered channel planform, as well as lacking large woody debris, pool features, and bank and buffer vegetation.

Figure 5.25. R16.S2.02-S1.01-A flows directly along Ward Brook Road for much of the segment.

R16.S2.02-S1.01-A Data Summary		Reference	Existing
Length: 3,425ft Drainage Area: 2.1 sq. mi. Evolution Stage: F-II Sensitivity: Very High	Confinement	Broad	Broad
	Stream Type	C_b	G
	Entrenchment Ratio	> 2.2	1.3
	Incision Ratio	< 1.2	2.3
	Dominant Bed Material	Cobble	Cobble
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Channel straightening, encroachment, lacking buffers, bank armoring, stormwater inputs**		

R16.S2.02-S1.01-B

The upstream segment on reach one of Kelley Brook is similar to segment A but has a narrower valley and is less incised. This segment is just over 3,600 feet in length beginning downstream about 1,400 feet above the culvert at 360 Ward Brook Road and ending upstream near 1309 Ward Brook Road (Appendix C, Map 8). More than half of this segment has been historically straightened due to the placement of Ward Brook Road and houses along it. Bank armoring and lacking buffers are common along this stretch of the brook, especially where it flows adjacent to the road. Bedrock grade controls are abundant within this segment (fifteen in total), which offer the brook vertical stability. Despite extensive straightening, R16.S2.02-S1.01-B has overall not undergone incision, likely due to the abundance of bedrock grade controls. The segment scored **reference** for geomorphic condition as a result of its lack of adjustments. R16.S2.02-S1.01-B is in **good** habitat condition and has a diversity of bed features including large woody debris and pools.

Figure 5.26. Bedrock grade controls are abundant in this segment.

R16.S2.02-S1.01-B Data Summary		**Reference**	**Existing**
Length: 3,611ft	Confinement	Broad	Narrow
Drainage Area: 2.1 sq. mi.	Stream Type	C_b	C_b
Evolution Stage: F-I	Entrenchment Ratio	> 2.2	2.6
Sensitivity: Moderate	Incision Ratio	< 1.2	1.0
	Dominant Bed Material	Cobble	Cobble
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Channel straightening, encroachment, lacking buffers, bank armoring, stormwater inputs**		

Herring Brook

Herring Brook is a tributary to Jones Brook that flows west to east and enters Jones Brook at the upstream end of reach R16.S2.03.

R16.S2.03-S1.01

Reach one on Herring Brook is located adjacent to Herring Brook Road between the confluence with Jones Brook downstream and just below Herring Lynch Trail upstream. The reach was divided into three segments during the assessment to account for changes in valley width and banks and buffers.

R16.S2.03-S1.01-A

Segment A is the downstream most segment on reach one of Herring Brook. The segment begins at the confluence with Jones Brook and extends upstream for just over 800 feet to where the brook enters the woods (Appendix C, Map 9). This segment is characterized by extensive historic channel straightening due to the presence of a house and Jones Brook Road within the river valley. This channel straightening has led to major historic incision. Bank armoring is also extensive in R16.S2.03-S1.01-A and is preventing the channel from widening, creating a deep and narrow channel. A stream type departure has occurred in segment A due to the historic incision and boundary conditions preventing channel evolution. R16.S2.03-S1.01-A is in **fair** geomorphic condition for the aforementioned reasons. Similarly, this segment is in **fair** habitat condition due to a lack of bed features caused by extensive straightening, lacking large woody debris, altered channel planform, and poorly vegetated banks and buffers.

Figure 5.27. Extensive riprap and straightening in R16.S2.03-S1.01-A.

R16.S2.03-S1.01-A Data Summary		**Reference**	**Existing**
Length: 832 ft	Confinement	Very Broad	Very Broad
Drainage Area: 4.4 sq. mi.	Stream Type	C	E
Evolution Stage: F-II	Entrenchment Ratio	> 2.2	4.4
Sensitivity: High	Incision Ratio	< 1.2	1.9
	Dominant Bed Material	Gravel	Cobble
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Channel straightening, bank armoring, lacking buffers**		

R16.S2.03-S1.01-B

The second segment on reach one of Herring Brook flows primarily through the woods adjacent to Herring Brook Road. The segment begins at the edge of the woods downstream and continues upstream for just over 1,700 feet to where the valley narrows between 423 and 493 Herring Brook Road (Appendix C, Map 9). R16.S2.03-S1.01-B appears to have undergone some historic channel straightening in the upper portion of the segment. Incision is currently occurring within this segment as evidenced through the presence of one headcut near the upstream end of the segment. This incision has led to a loss of floodplain access and stream type departure in most of the segment. Channel widening is also an active process in this segment; bank erosion is common, particularly in the upper part of the segment. R16.S2.03-S1.01-B is in **fair** geomorphic condition for these reasons. Although the stream channel is actively adjusting in this segment, there is abundant large woody debris, instream cover, and pool habitat, and the banks and buffers are generally well forested. These factors led to the placement of this segment in **good** habitat condition.

Figure 5.28. Headcut in R16.S2.03-S1.01-B.

R16.S2.03-S1.01-B Data Summary		Reference	Existing
Length: 1,725 ft	Confinement	Broad	Broad
Drainage Area: 4.4 sq. mi.	Stream Type	C	F
Evolution Stage: F-II	Entrenchment Ratio	> 2.2	1.1
Sensitivity: Very High	Incision Ratio	< 1.2	2.4
	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Channel straightening, bank erosion, lacking buffers, headcut**		

R16.S2.03-S1.01-C

The upstream most segment on reach one of Herring Brook is roughly 2,400 feet in length and flows through a broad valley. Sections of the brook flow directly along Herring Brook Road and/or houses along the road and were likely historically straightened, while other sections flow through the woods and have minimal human impacts (Appendix C, Map 9). Very minor incision was observed at the cross section for this segment, and scattered minor bank erosion indicates that widening may be occurring in some sections of this segment. Riparian buffers are lacking in this segment, particularly on the northern side of the channel where infrastructure is common. Overall, major adjustment is not occurring within this segment and, for this reason, it was placed in **good** geomorphic condition. R16.S2.03-S1.01-C is also in **good** habitat condition with its ample large woody debris, nice pools, good floodplain connectivity, and mostly well forested banks and buffers.

Figure 5.28. Downstream view at cross section in R16.S2.03-S1.01-C.

R16.S2.03-S1.01-C Data Summary		**Reference**	**Existing**
Length: 2,368 ft Drainage Area: 4.4 sq. mi. Evolution Stage: F-I Sensitivity: High	Confinement	Broad	Broad
	Stream Type	C	C
	Entrenchment Ratio	> 2.2	4.5
	Incision Ratio	< 1.2	1.2
	Dominant Bed Material	Gravel	Cobble
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Bank erosion, lacking buffers, bank armoring, channel straightening**		

5.2 Stream Crossings

The Vermont Culvert Geomorphic Compatibility Screen Tool and the Vermont Aquatic Organism Passage Coarse Screen Tool (Appendix B pages 1 through 3) were used to evaluate bridges and culverts within the Phase 2 study area. Of the 18 bridges and culverts assessed, none were determined to be "fully incompatible," six are "mostly incompatible," six are "partially compatible," six are "mostly compatible," and none are "fully compatible."

Tables 6 and 7 in Appendix B (pages 4 and 5) summarize the data collected for the assessed structures and recommendations for replacement of the structures. One bridge and two culverts within the study area have been recommended for replacement at a high priority. Two bridges and four culverts are recommended for replacement at a moderate priority, two bridges at a low priority, and five bridges and two culverts are not recommended for replacement at all. This information can be used by municipalities and the Vermont Agency of Transportation to prioritize bridge and culvert replacements.

6.0 PRELIMINARY PROJECT IDENTIFICATION

Phase 2 Stream Geomorphic data were analyzed for the Mad River and Jones Brook watersheds in order to determine major stressors and impacts to each stream segment. These data were used to identify potential projects to mitigate adverse impacts, increase geomorphic stability, and improve habitat throughout the study area. Many projects utilize restoration and conservation strategies to bring the study streams closer to equilibrium conditions.

6.1 Project Identification

A total of 43 projects were identified within the study area. These include a variety of types of projects, such as riparian buffer plantings, river corridor easements, berm removals, bridge and culvert replacements, and more. Detailed information about proposed projects can be found in Appendix C. Projects were categorized and reported according to standards set by the Vermont Watershed Management Division using its Watershed Projects Database table. Based on these standards, five types of projects were identified within the Phase 2 study area: Agricultural Pollution Prevention - Preliminary Design, Dam Removal - Preliminary Design, Floodplain/Stream Restoration - Preliminary Design, River - Planting, and River Corridor Easement – Design. Examples of types of these projects are shown in the table below.

Project Type	Project Examples	Flood Resiliency and Habitat Enhancement Measures
Agricultural Pollution Prevention - Preliminary Design	➢ Livestock exclusion	➢ Improve physical stability and habitat condition of a river by excluding livestock from accessing it; also allow buffer regeneration at previous access points. ➢ Improve water quality.
Dam Removal - Preliminary Design	➢ Investigate dam removal or retrofit	➢ Remove unused dams to improve aquatic organism passage and channel stability. ➢ Retrofit existing dams to improve aquatic organism passage.
Floodplain/Stream Restoration - Preliminary Design	➢ Berm removal ➢ Bridge/culvert replacement ➢ Road relocation ➢ Floodplain creation ➢ Investigate gully remediation	➢ Remove berms to improve stream access to floodplains. ➢ Windrowing can disconnect streams from their floodplains through excavation and berming. Return windrowed material to a channel or remove it to improve floodplain access. ➢ Remove river-road conflicts by relocating vulnerable infrastructure. Improve floodplain access to provide storage of floodwaters and sediment. ➢ Incorporate ecologically-based stream crossings with natural channel bottom to improve aquatic organism passage. Structures that mimic the natural stream channel are more flood resilient. ➢ Upgrade undersized structures to reduce road washouts. ➢ Remove abandoned bridges and culverts to improve channel stability and water quality. ➢ Retrofit newer culverts to improve aquatic organism passage. ➢ Investigate gullies and determine feasibility of remediation for water quality improvement and increased channel stability.
River - Planting	➢ Riparian buffer planting	➢ Plant native tree and shrub species to restore riparian habitat, provide floodplain roughness and cover along banks, and stabilize eroding banks.
River Corridor Easement – Design	➢ River corridor easement	➢ Adopt river corridor and/or conservation easements on large tracts of land to provide room for the river to reach an equilibrium condition and protect against new encroachments. ➢ Protect floodplains and wetland habitat to preserve floodwater and sediment storage.

6.2 Program Descriptions

River Restoration and Conservation Programs

There are a number of federal, state, and local programs available for river restoration and protection. Funding sources provided below could be leveraged for further project development and implementation. These programs are as follows:

- ANR River Corridor Easement Program (RCE)
- Ecosystem Restoration Program (ERP)
- Conservation Reserve Enhance Program (CREP)
- Trees for Streams (TFS)
- Environmental Quality Incentives Program (EQIP)
- Wildlife Habitat Incentives Program (WHIP)
- Wetland Reserve Program (WRP)

River Corridor Easement

The River Corridor Easement is designed to promote the long-term physical stability of the river by allowing the river to achieve a state of equilibrium (where sediment and water loads are in balance). River corridor easements are vital for a passive geomorphic restoration approach and can also be used for conserving rivers that are in good condition (equilibrium). Rivers that are in equilibrium have access to their floodplains and therefore experience less erosion and negative impacts from flooding events. Corridor easements are a high priority for reaches that are not in equilibrium; these channels are experiencing channel adjustments, which are causing conflicts with current/future land-use expectations. Providing an easement on these reaches reduces the conflict and provides a long-term solution to sediment storage and flood water attenuation needs.

- Easements are in perpetuity, meaning the agreement stays with the land forever.
- A onetime payment is received by the landowner for transferal of channel management rights to a second party (a land trust).
- Transferal of channel management rights means that the landowner would no longer be able to rock line river banks or remove gravel for personal use.
- A RCE requires a minimum 50 foot buffer that floats with the river. No active land-use is allowed within the buffer. The buffer can be actively planted or allowed to revegetate passively.
- The easement does not take away the agricultural land-use rights, so the landowner could continue to crop or pasture the farm land mapped outside of the buffer, yet within the corridor, for as long as the river allows.

Ecosystem Restoration Program

The Ecosystem Restoration Program within the Clean Water Initiative, formerly called the Clean and Clear Program, is a Vermont program designed to improve water quality by addressing one or more of the following areas: stream stability, protecting against flood hazards, enhancing instream and riparian habitat, reducing stormwater runoff, restoring riparian wetlands, enhance the environmental and economic sustainability of agricultural lands. Funding is available for project identification, project development and project implementation. Vermont municipalities, local or regional governmental agencies, non-profit organizations, and citizens groups are eligible to receive funding.

Conservation Reserve Enhancement Program

The USDA Farm Service administers a program called the Conservation Reserve Enhancement Program that helps agricultural producers to take farmland out of production in sensitive areas, such as river corridors. This helps to improve water quality and restore wildlife habitat.

- CREP can be either a 15 or 30 year contract to plant trees.
- 90% of the practice costs are covered with the remaining 10% either resting with the participants or could be paid by the US Partners for Fish and Wildlife. Examples of the practice costs include fencing, watering facilities, and trees. There are some costs that are capped, but generally all the practice costs can be paid through the program.
- To provide additional incentives to enroll in CREP, the program offers upfront and annual rental payments for the land where agricultural production is lost during the contract period.

Trees for Streams

Programs offered by the US Fish and Wildlife Service or through State funding to work with local partners and landowners to restore native streamside vegetation along river banks.

Environmental Quality Incentives Program

EQIP is a voluntary program available through the Natural Resources Conservation Service (NRCS) that provides financial and technical assistance to implement conservation practices to meet local environmental regulations. Owners of land in agricultural or forest production are eligible for the program. Contracts with landowners can be up to ten years in length.

Wildlife Habitat Incentives Program

WHIP is a voluntary program offered to landowners to improve wildlife habitat on their land. Owners of agricultural land, nonindustrial private forest land, and Native American land are eligible. Technical assistance and up to 75 percent cost-share is available to improve fish and wildlife habitat.

Wetland Reserve Program

WRP is a voluntary program offered by NRCS to landowners to protect, restore and enhance wetlands on their property. NRCS provides technical assistance and financial support for projects that establish long-term conservation and wildlife practices and protection.

Flood Resiliency Programs and Initiatives

Additionally, there are numerous programs in place to aid communities in becoming more flood resilient. A collection of several of these programs follows:

- Vermont Emergency Relief Assistance Fund (ERAF)
- Vermont Municipal Planning Grants (MPG)
- Clean Water State Revolving Fund
- National Flood Insurance Program Community Rating System (CRS)
- U.S. Department of Housing and Urban Development Community Development Block Grants (CDBG)
- Federal Emergency Management Agency Buyout Program
- Vermont Agency of Natural Resources River Corridor Protection

Emergency Relief Assistance Fund

In 2014, the state of Vermont established an Emergency Relief Assistance Fund (ERAF) to provide matching funding for federal assistance after federally-declared disasters. This program allows towns in Vermont to increase the amount of state aid money they could receive as a match to federal aid for post-disaster recovery. By taking certain steps to become more prepared and resilient, a town can be eligible for increased state aid money. Certain damage costs from federally-declared disasters are reimbursed 75% by federal money. The state of Vermont contributes a minimum of 7.5% of the total cost, but if a town takes additional steps, the state aid can increase to 12.5% or 17.5% of the cost, leaving less for the town itself to pay (State, 2015). The table below shows the ERAF status for Moretown, Vermont.

Town ERAF Rating	Moretown 12.5%
12.5%	
Participate in the National Flood Insurance Program	X
Adopt 2013 Road & Bridge Standards	X
Adopt a Local Emergency Operations Plan	X
Adopt a Local Hazard Mitigation Plan	X
17.5% (need one to quality)	
Protect River Corridors from new encroachment	
Protect flood hazard areas from new encroachments and participate in the FEMA Community Rating System	

Vermont Municipal Planning Grants Program

The Vermont Department of Housing and Community Development has established the MPG program to support local planning and revitalization initiatives for municipalities. Funding can go toward such projects as municipal and hazard mitigation plan updates, natural resource inventories, and flood resiliency planning. Grants over $8,000 in value require small cash matching funds (ACCD, 2015).

Clean Water State Revolving Fund
The Clean Water State Revolving Fund is a program sponsored by the Vermont Department of Environmental Conservation to minimize water pollution that occurs as a result of wastewater treatment operations and stormwater. Municipalities can apply for funding for design and implementation of such projects as wastewater treatment facility upgrades, repairs to municipal wastewater and stormwater infrastructure, development of stormwater infrastructure, and repair of homeowner on-site wastewater treatment systems. Upgrades could improve wastewater utilities by flood-proofing and making infrastructure more flood resilient.

National Flood Insurance Community Rating System
In 1990, the National Flood Insurance Program implemented the Community Rating System, which is a voluntary program aimed at encouraging floodplain management activities that exceed NFIP minimum standards. The program allows communities to reduce their flood insurance payments by engaging in any of nineteen qualified activities that fall into the categories of

- Public Information
- Mapping and Regulations
- Flood Damage Reduction, and
- Warning and Response.

This program not only reduces flood insurance costs, it improves community flood resiliency and can reduce future damage and losses (FEMA, 2017).

U.S. Department of Housing and Urban Development Community Development Block Grants
The CDBG program provides communities with resources to address community development needs. Funding is available for recovery assistance after federally-declared disasters, as well as in the form of state administered grants.

FEMA Buyouts
Property acquisition, also known as buyouts, is a hazard mitigation assistance program offered through FEMA. Buyouts involve the purchase of at-risk properties by municipalities with 75% FEMA Hazard Mitigation Grant Program money and 25% municipality money. These properties are purchased for fair market (pre-disaster if disaster has occurred). The properties are required to be cleared and left in open space indefinitely. A buyout property may never be sold or developed again (FEMA, 2014).

VANR River Corridor Protection
In 2014, the Vermont Agency of Natural Resources developed river corridors on a state-wide scale. The purpose of defining and regulating river corridors is to prevent increases in man-made conflicts that can result from development in identified river corridor areas; minimize property loss and damage due to fluvial erosion; and prohibit land-uses and development in river corridors that pose a danger to health and safety. Additionally, river corridor delineation

and protection facilitates stream stability and dynamic equilibrium. By limiting conflicts between rivers and development, management actions that lead to channel instability are also limited. The basis of a river corridor is a defined area which includes the course of a river and its adjacent lands. The width of the corridor is defined by many model parameters, and may be modified to incorporate field verified data. Certain development is limited within the delineated river corridor, but corridors can be further protected by adopting development regulations at the municipality level. More information on ANR river corridor protection can be found at:
http://www.watershedmanagement.vt.gov/rivers.htm

Transportation Improvement Programs

Several state programs exist to assist Towns with transportation infrastructure improvement. Among these are the Transportation Alternatives Program and the Vermont Better Roads Program, which are both offered through the Vermont Agency of Transportation.

Transportation Alternatives Program
This program funds environmental mitigation activities that are related to transportation. It focuses specifically on stormwater related projects and funds the following types of projects: planning studies, salt/sand sheds, vactor trucks/high efficiency sweepers, bank stabilization, detention ponds, check dams, swirl separators, permeable pavers, infiltration basins, gravel wetlands, subsurface detention systems, bio filters, and bio retention systems. VTrans provides more information on the grant program at:
http://vtrans.vermont.gov/highway/local-projects/transport-alt

Vermont Better Roads Program
VTrans defines the Better Roads Program as “a grant program for municipalities that provides funds for planning and erosion control projects that improve water quality and reduce maintenance costs.” It provides towns funding and technical assistance to implement erosion control projects on town roads that support the goal of improving water quality. More information on this grant program can be found at:
http://vtrans.vermont.gov/highway/better-roads

6.3 Next Steps

There are many opportunities to restore the Mad River and Jones Brook watersheds to a more stable condition. Proposed projects are part of a greater strategy to recover from Tropical Storm Irene through improving flood resiliency in the watershed. Further, the implementation of river corridor protection is recommended to restrict future development within the river corridor, minimize damage to infrastructure during flood events, and save money on flood recovery.

Specific steps recommended following this study are as follows:

- Outreach to private landowners and the public about the plan and potential restoration and protection opportunities.
- Meetings held with project partners and landowners to prioritize projects and discuss implementation.
- Apply to funding sources for implementation grants.
- Phase 3 stream survey work where applicable for restoration projects.
- Implementation of priority projects with project partners and landowners.

For additional information about project development, please contact the Vermont River Management Program or Central Vermont Regional Planning Commission.

In addition to site-specific projects, Moretown can take steps to become more flood resilient. Modifying existing zoning regulations at the municipality level could protect buildings and infrastructure from future flood damage and losses. For example, new development could be restricted to outside of mapped flood hazard areas only. These communities could also participate at the highest level of the Vermont ERAF program, which can involve joining the NFIP Community Rating System.

7.0 LIST OF ACRONYMS AND GLOSSARY OF TERMS

List of Acronyms

ACCD – Agency of Commerce and Community Development
BCE – Bear Creek Environmental, LLC
CDBG – Community Development Block Grant
CREP – Conservation Reserve Enhancement Program
CRS – Community Rating System
CVRPC – Central Vermont Regional Planning Commission
EQIP – Environmental Quality Incentives Program
ERAF – Emergency Relief Assistance Fund
ERP – Ecosystem Restoration Program
GIS – Geographic Information System
FEMA – Federal Emergency Management Agency
MPG – Municipal Planning Grant
NFIP – National Flood Insurance Program
NWI – National Wetlands Inventory
QA/QC – quality assurance/quality control
RCE – ANR River Corridor Easement Program
RHA- Rapid Habitat Assessment
RGA-Rapid Geomorphic Assessment
SGA – Stream Geomorphic Assessment
SGAT – Stream Geomorphic Assessment Tool
TFS – Trees for Streams
TRORC – Two Rivers-Ottauquechee Regional Commission
TSI – Tropical Storm Irene
US ACOE – United States Army Corps of Engineers
USGS – United States Geological Survey
VANR – Vermont Agency of Natural Resources
VTDEC – Vermont Department of Environmental Conservation
VDFW _ Vermont Department of Fish and Wildlife
WHIP – Wildlife Habitat Incentives Program
WRP – Wetland Reserve Program

Glossary of Terms

Adapted from:
Restoration Terms, by Craig Fischenich, February, 2000, USAE Research and Development Center, Environmental Laboratory, 3909 Halls Ferry Rd., Vicksburg, MS 39180
And
Vermont Stream Geomorphic Assessment Handbook, Appendix Q, 2009, VT Agency of Natural Resources, Waterbury, VT.
http://www.vtwaterquality.org/rivers/docs/assessmenthandbooks/rv_apxqglossary.pdf

Adjustment Process – type of change that is underway due to natural causes or human activity that has or will result in a change to the valley, floodplain, and/or channel condition (e.g., vertical, lateral, or channel plan form adjustment processes).

Aggradation - A progressive buildup or rising of the channel bed and floodplain due to sediment deposition. The geologic process by which streambeds are raised in elevation and floodplains are formed. Aggradation indicates that the stream discharge and/or bed load characteristics are changing. Opposite of degradation.

Alluvial Fan – A fan-shaped accumulation of alluvium (alluvial soils) deposited at the mouth of a ravine or at the juncture of a tributary stream with the main stem where there is an abrupt change in slope.

Alluvial Soils – Soil deposits from rivers.

Alluvium – A general term for detrital deposits made by streams on riverbeds, floodplains, and alluvial fans.

Avulsion – A change in channel course that occurs when a stream suddenly breaks through its banks, typically bisecting an overextended meander arc.

Bank Stability – The ability of a stream bank to counteract erosion or gravity forces.

Bankfull Channel Depth - The maximum depth of a channel within a riffle segment when flowing at a bankfull discharge.

Bankfull Channel Width - The top surface width of a stream channel when flowing at a bankfull discharge.

Bankfull Discharge - The stream discharge corresponding to the water stage that overtops the natural banks. This flow occurs, on average, about once every 1 to 2 years and given its frequency and magnitude is responsible for the shaping of most stream or river channels.

Bar – An accumulation of alluvium (usually gravel or sand) caused by a decrease in sediment transport capacity on the inside of meander bends or in the center of an over wide channel.

Berms – Mounds of dirt, earth, gravel or other fill built parallel to the stream banks designed to keep flood flows from entering the adjacent floodplain.

Bifurcated Channel – a river channel that has split into two branches as a result of planform adjustment (i.e. split flow due to island).

Boundary Conditions – Factors that are acting upon a stream and preventing adjustment (e.g. bank armoring prevents channel widening).

Cascade – River bed form where the channel is very steep with narrow confinement. There are often large boulders and bedrock with waterfalls.

Channelization – The process of changing (usually straightening) the natural path of a waterway.

Confluence – The location where two streams flow together.

Culvert – A buried pipe that allows flows to pass under a road.

Degradation – (1) A progressive lowering of the channel bed due to scour. Degradation is an indicator that the stream's discharge and/or sediment load is changing. The opposite of aggradation. (2) A decrease in value for a designated use.

Delta Bar – A deposit of sediment where a tributary enters the main stem of a river.

Depositional Features – Types of sediment deposition and storage areas in a channel (e.g. mid-channel bars, point bars, side bars, diagonal bars, delta bars, and islands).

Diagonal Bar – Type of depositional feature perpendicular to the bank that is formed from excess sedimentation and within the channel and from the development of steep riffles.

Drainage Basin – The total area of land from which water drains into a specific river.

Dredging – Removing material (usually sediments) from wetlands or waterways, usually to make them deeper or wider.

Erosion – The wearing away of rock or soil by the gradual detachment of soil or rock fragments by water, wind, ice, and other mechanical, chemical, or biological forces.

Flood Resiliency – The ability to withstand and recover from flooding and associated damages.

Floodplain – Land built of sediment that is regularly covered with water as a result of the flooding of a nearby stream.

Floodprone Width – the wetted width of the channel when the water level is twice the maximum bankfull depth. For most channels this is associated with less than a 50 year return period (Rosgen, 1996).

Fluvial Erosion – Erosive forces created by flowing water.

Fluvial Geomorphology – the physics of flowing water, sediments, and other products of watersheds in relation to various land forms.

Gaging Station – A particular site in a stream, lake, reservoir, etc., where hydrologic data are obtained.

Grade Control - A fixed feature on the streambed that controls the bed elevation at that point, effectively fixing the bed elevation from potential incision; typically bedrock, dams or culverts.

Gradient – Vertical drop per unit of horizontal distance.

Habitat – The local environment in which organisms normally grow and live.

Headwater – Referring to the source of a stream or river.

Headcut – Sudden change in elevation or knickpoint on a streambed. Headcutting is the process by which a streambed lowers as headcuts migrate upstream.

Inundation Flooding – Submersion of low-lying areas surrounding a stream by slowly flowing or standing water.

Incised River – A river that erodes its channel by the process of degradation to a lower base level than existed previously or is consistent with the current hydrology.

Islands – Mid-channel bars that are above the average water level and have established woody vegetation.

Lacustrine Soils- Soil deposits from lakes.

Mass Failure – A landslide that has occurred adjacent to a stream and on its valley wall. Involves mass slumping of land down the valley wall.

Meander - The winding of a stream channel, usually in an erodible alluvial valley. A series of sine-generated curves characterized by curved flow and alternating banks and shoals.

Meander Migration – The change of course or movement of a channel. The movement of a channel over time is natural in most alluvial systems. The rate of movement may be increased if the stream is out of balance with its watershed inputs.

Meander Belt Width – The horizontal distance between the opposite outside banks of fully developed meanders determined by extending two lines (one on each side of the channel) parallel to the valley from the lateral extent of each meander bend along both sides of the channel.

Meander Wavelength - The lineal distance downvalley between two corresponding points of successive meanders of the same phase.

Meander Wavelength Ratio – The meander wavelength divided by the bankfull channel width.

Meander Width Ratio – The meander belt width divided by the bankfull channel width.

Mid-Channel Bar – Sediment deposits (bar) located in the channel away from the banks, generally found in areas where the channel runs straight. Mid-channel bars caused by recent channel instability are unvegetated.

Neck Cutoff – This is the occurrence of an avulsion on the inside of a very long and tight meander.

Planform - The channel shape as if observed from the air. Changes in planform often involve shifts in large amount of sediment, bank erosion, or the migration of the channel.

Plane Bed – Channel lacks discrete bed features (such as pools, riffles, and point bars) and may have long stretches of featureless bed.

Point Bar –The convex side of a meander bend that is built up due to sediment deposition.

Pool -- A habitat feature (section of stream) that is characterized by deep, low-velocity water and a smooth surface.

Reach - Section of river with similar characteristics such as slope, confinement (valley width), and tributary influence.

Restoration – The return of an ecosystem to a close approximation of its condition prior to disturbance.

Riffle - A habitat feature (section of stream) that is characterized by shallow, fast-moving water broken by the presence of rocks and boulders.

Riffle-pool - Channel has undulating bed that defines a sequence of riffles, runs, pools, and point bars. Occurs in moderate to low gradient and moderately sinuous channels, generally in unconfined valleys with well-established floodplains.

Riparian Buffer – The width of naturally vegetated land adjacent to the stream between the top of the bank and the edge of other land-uses. A buffer is largely undisturbed and consists of the trees, shrubs, groundcover plants, duff layer, and naturally uneven ground surface.

Riparian Corridor – Lands defined by the lateral extent of a stream's meanders necessary to maintain a stable stream dimension, pattern, profile, and sediment regime.

Segment – A relatively homogeneous section of stream contained within a reach that has the same reference stream characteristics but is distinct from other segments in the reach.

Sensitivity – The valley, floodplain and/or channel condition's likelihood to change due to natural causes and/or anticipated human activity.

Side Bar – Unvegetated sediment deposits located along the margins or the channel in locations other than the inside of channel meander bends.

Step-Pool – Characterized by longitudinal steps formed by large particles (boulder/cobbles) organized into discrete channel-spanning accumulations that separate pools, which contain smaller sized materials. Often associated with steep channels in confined valleys.

Steep Riffle – Associated with aggradation where sediment has dropped out to form a steep face of sediment on the downstream side.

Surficial Sediment/Geology – Sediment that lies on top of bedrock.

Tributary – A stream that flows into another stream, river, or lake.

Tributary Rejuvenation – As the bed of the main stem is lowered, head cuts (incision) begin at the mouth of the tributary and move upstream.

Urban Runoff – Storm water from city streets and gutters that usually carries a great deal of litter and organic and bacterial wastes into the receiving waters.

Valley Wall – The edge of a river valley where the slope of the land increases and a stream is unlikely to ever flow beyond.

8.0 REFERENCES

Federal Emergency Management Agency. 2014. Hazard Mitigation Assistance – Property Acquisition (Buyouts). Available at: https://www.fema.gov/application-development-process/hazard-mitigation-assistance-property-acquisition-buyouts

Federal Emergency Management Agency. 2017. Community Rating System Fact Sheet. Available at: https://www.fema.gov/media-library-data/1507029324530-082938e6607d4d9eba4004890dbad39c/NFIP_CRS_Fact_Sheet_2017_508OK.pdf

Milone & MacBroom, Inc. 2008. The Vermont Culvert Geomorphic Compatibility Screening Tool. South Burlington, Vermont.

Montgomery, David and Buffington, John. 1997. Channel Reach Morphology in Mountain Basins. GSA Bulletin. Boulder, Colorado.

Rosgen, Dave. 1996. Applied River Morphology. Pagosa Springs, Colorado.

Ryan, J. 2001. Stream Stability Assessment of Lamoille County, Vermont. Washington, Vermont.

State of Vermont, 2015. Emergency Relief and Assistance Fund. Flood Ready Vermont. Available at: http://floodready.vermont.gov/find_funding/emergency_relief_assistance

Thompson, Elizabeth and Sorenson, Eric. 2000. Wetland, Woodland, Wildland: A Guide to the Natural Communities of Vermont. Montpelier, Vermont.

United States Geological Survey. 2017. Mad River near Moretown, VT. Accessed in January 2018 and available at http://waterdata.usgs.gov/nh/nwis/current/?type=flow

United States Geological Survey. 2017. Winooski River at Montpelier, Vermont. Accessed in January 2018 and available at http://waterdata.usgs.gov/nh/nwis/current/?type=flow

Vermont Agency of Administration, Office of the Secretary. June 2012. Vermont Recovering Stronger – Irene Recovery Status Report. Montpelier, Vermont.

Vermont Agency of Commerce and Community Development. 2015. Municipal Planning Grants FY 2015. Department of Housing and Community Development. Available at: http://accd.vermont.gov/sites/accd/files/Documents/strongcommunities/cd/mpg/MPG_Overview_FY15.pdf

Vermont Agency of Natural Resources. 2004. Appendix C, Channel Evolution Models. DEC River Management Program. Waterbury, Vermont.

Vermont Agency of Natural Resources. 2007. Vermont Stream Geomorphic Assessment Phase 1 Handbook: Watershed Assessment Using Maps, Existing Data, and Windshield Surveys. DEC River Management Program. Waterbury, Vermont.

Vermont Agency of Natural Resources. 2008. Draft Instructions for the Vermont Rapid Habitat Assessment (RHA). DEC River Management Program. Waterbury, Vermont.

Vermont Agency of Natural Resources. 2009a. Appendix G, Bridge and Culvert Assessment. DEC River Management Program. Waterbury, Vermont.

Vermont Agency of Natural Resources. 2009b. Vermont Agency of Natural Resources Phase 2 Handbook, Rapid Stream Assessment Field Protocols. DEC River Management Program. Waterbury, Vermont.

Vermont Agency of Natural Resources. 2010a. Vermont Agency of Natural Resources River Corridor Planning Guide to Identify and Develop River Corridor Protection and Restoration Projects. DEC River Management Program. Waterbury, Vermont.

Vermont Agency of Natural Resources. 2010b. Municipal Guide to Fluvial Erosion Hazard Mitigation. DEC River Management Program. Waterbury, Vermont

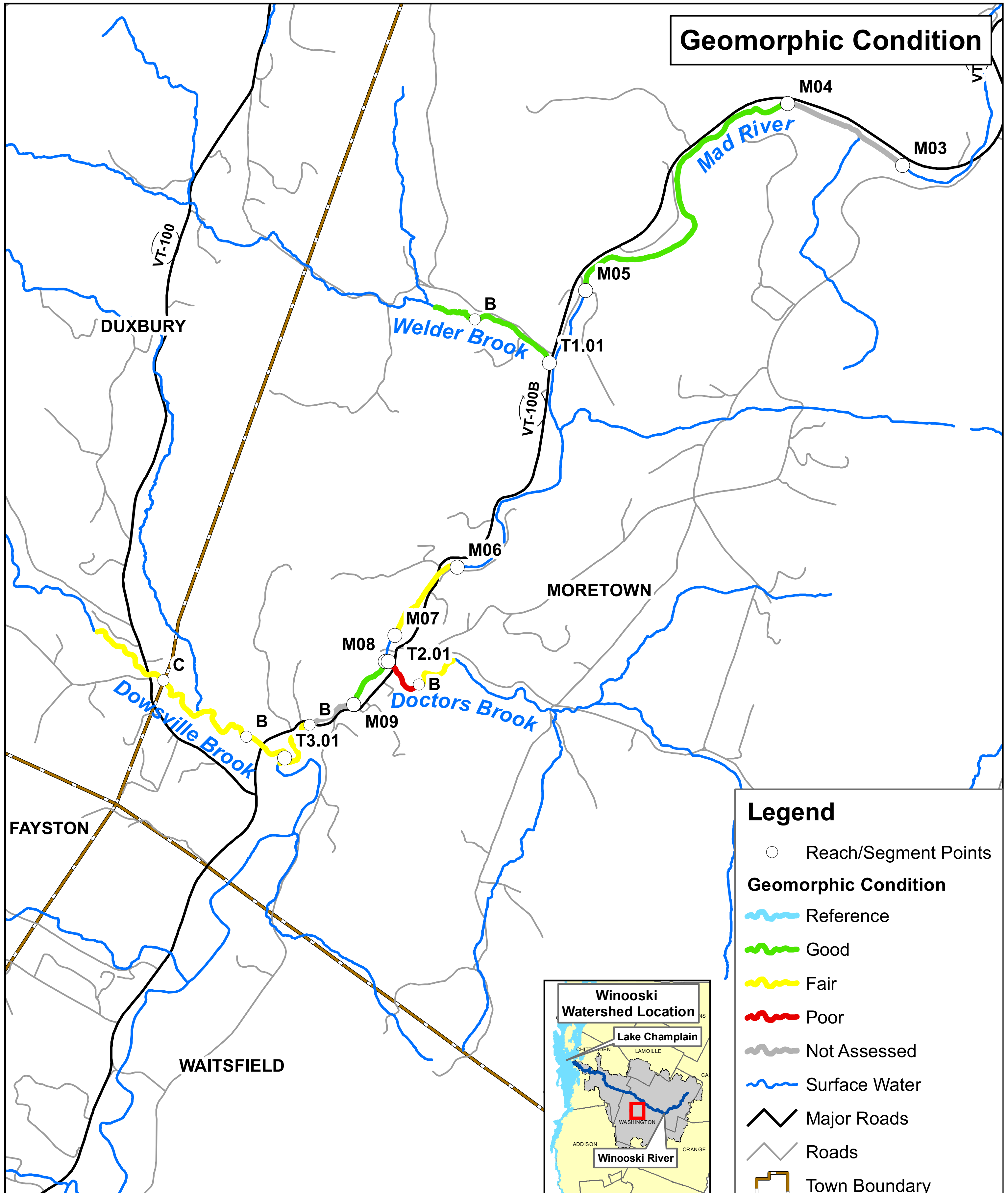
Vermont Agency of Natural Resources. 2012a. Lessons From Irene: Building Resiliency as we rebuild. Available at: http://anr.vermont.gov/sites/anr/files/specialtopics/climate/documents/factsheets/Irene_Facts.pdf

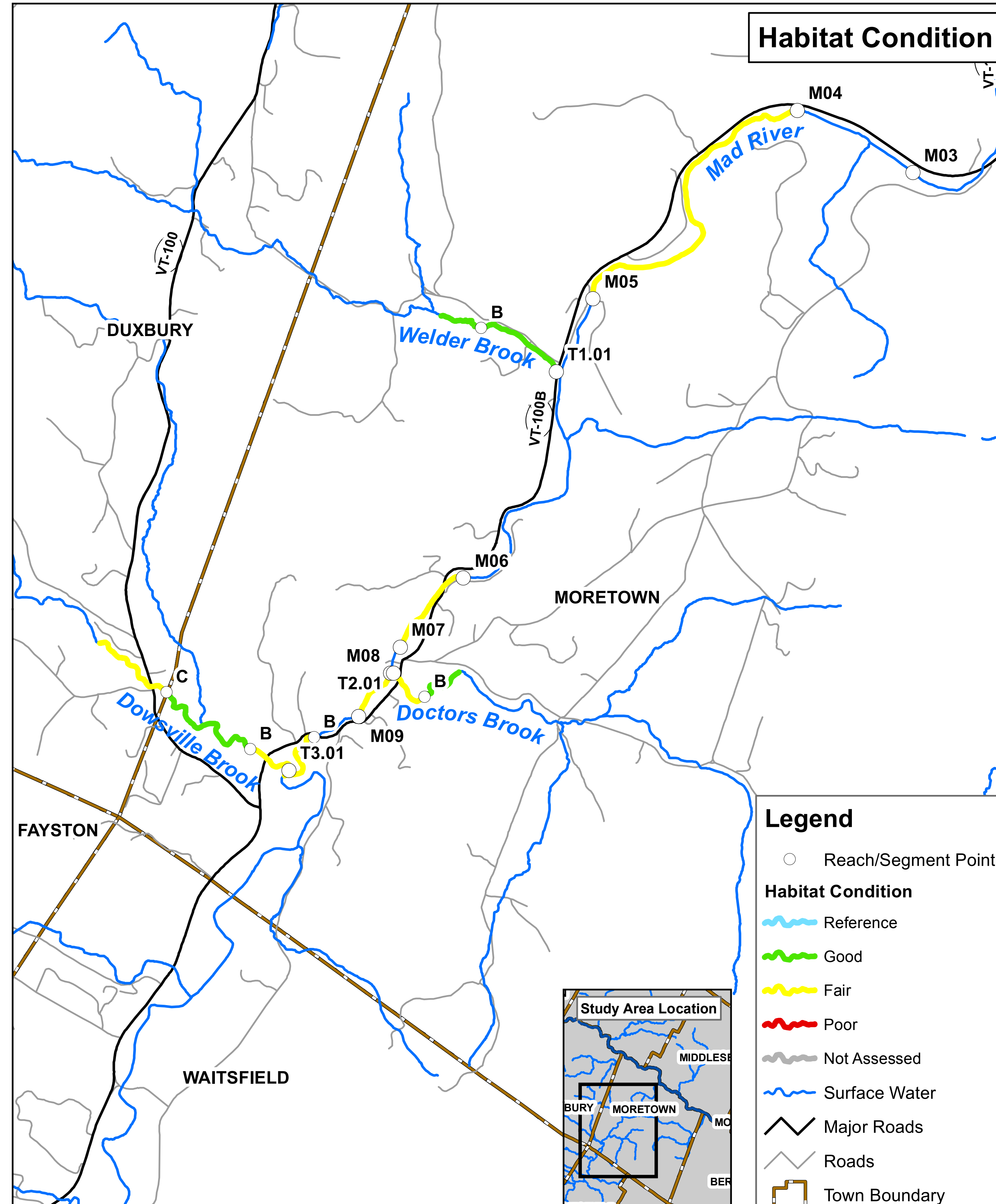
Vermont Agency of Natural Resources. 2012b. Winooski River Basin Water Quality Management Plan. Available at: http://www.watershedmanagement.vt.gov/planning/htm/pl_winooskibasin.htm

Vermont Agency of Natural Resources (VANR). 2017. Natural Resources Atlas. Available at: http://anrmaps.vermont.gov/websites/anra5/

APPENDIX A

Maps



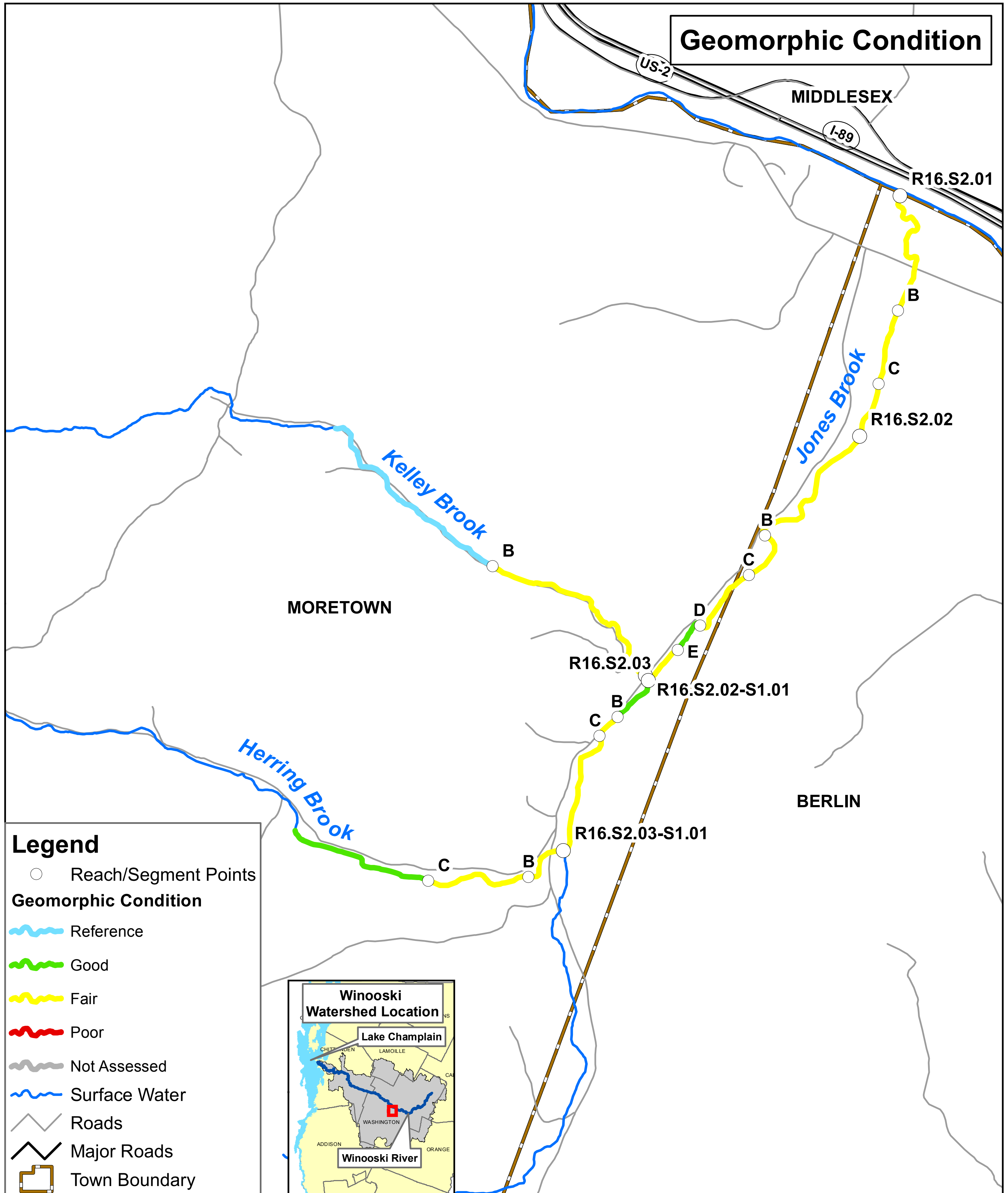


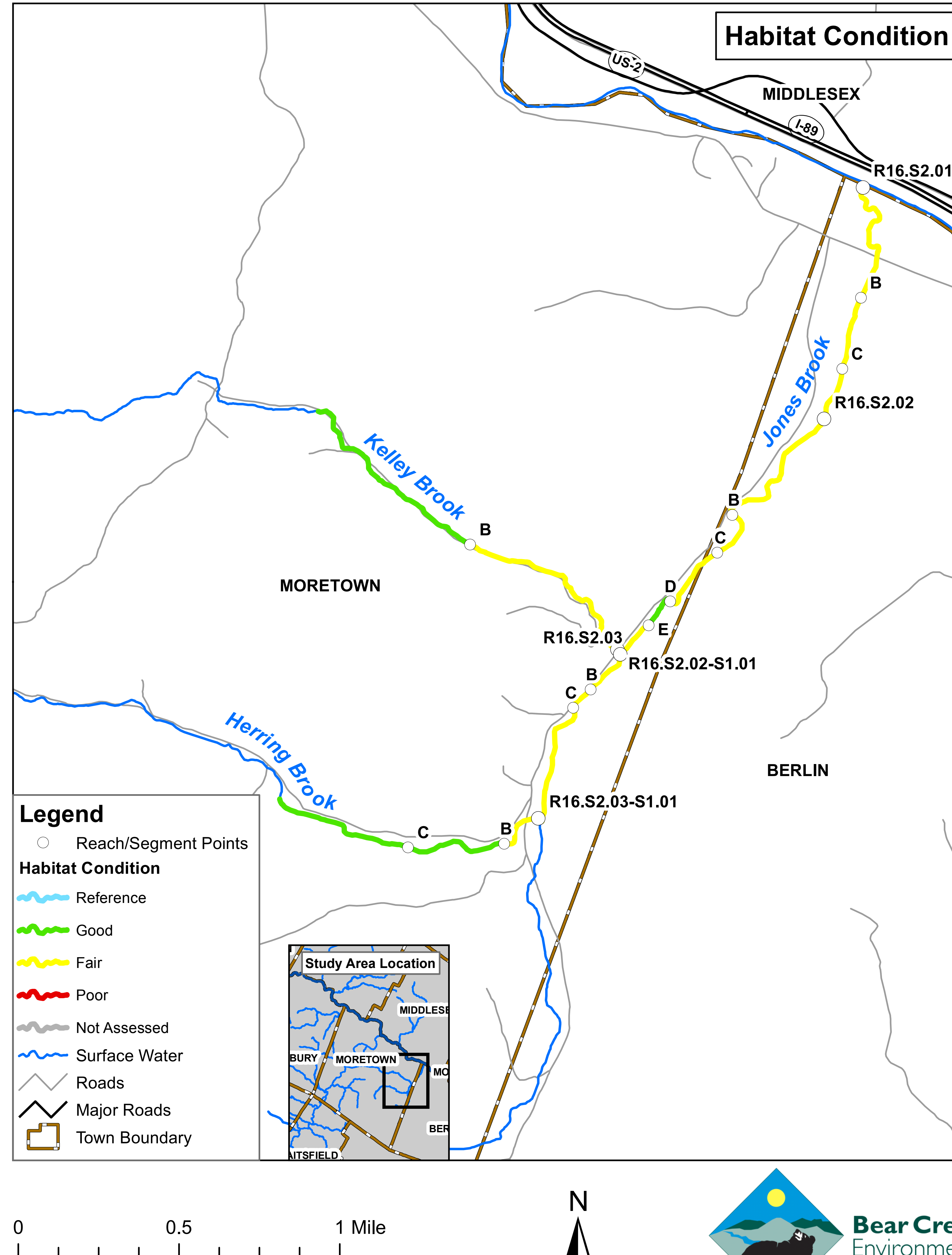
Mad River, Welder Brook, Doctors Brook, & Dowsville Brook Stream Condition Moretown, Vermont

0 0.95 1.9 Miles

N

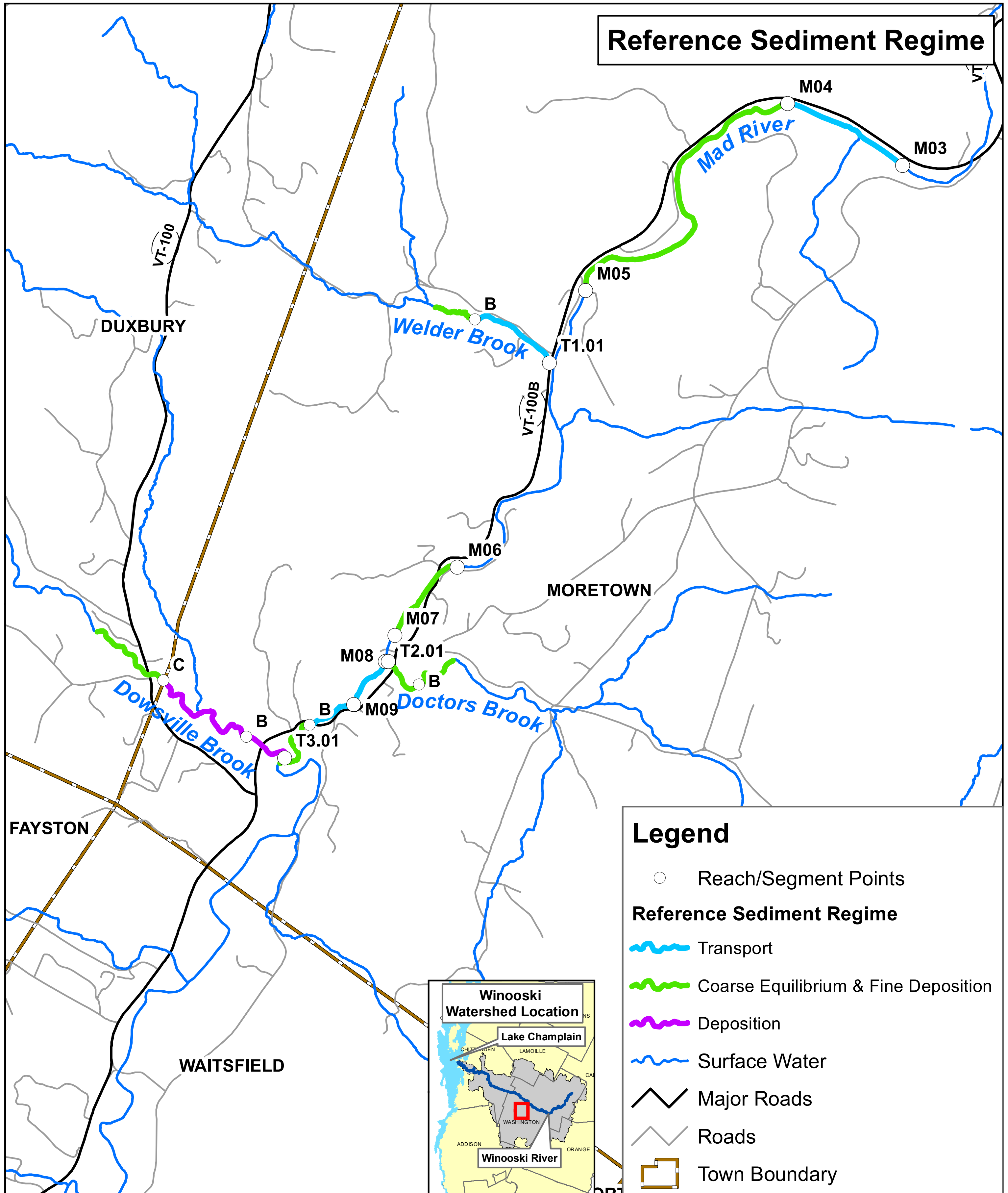
Bear Creek Environmental

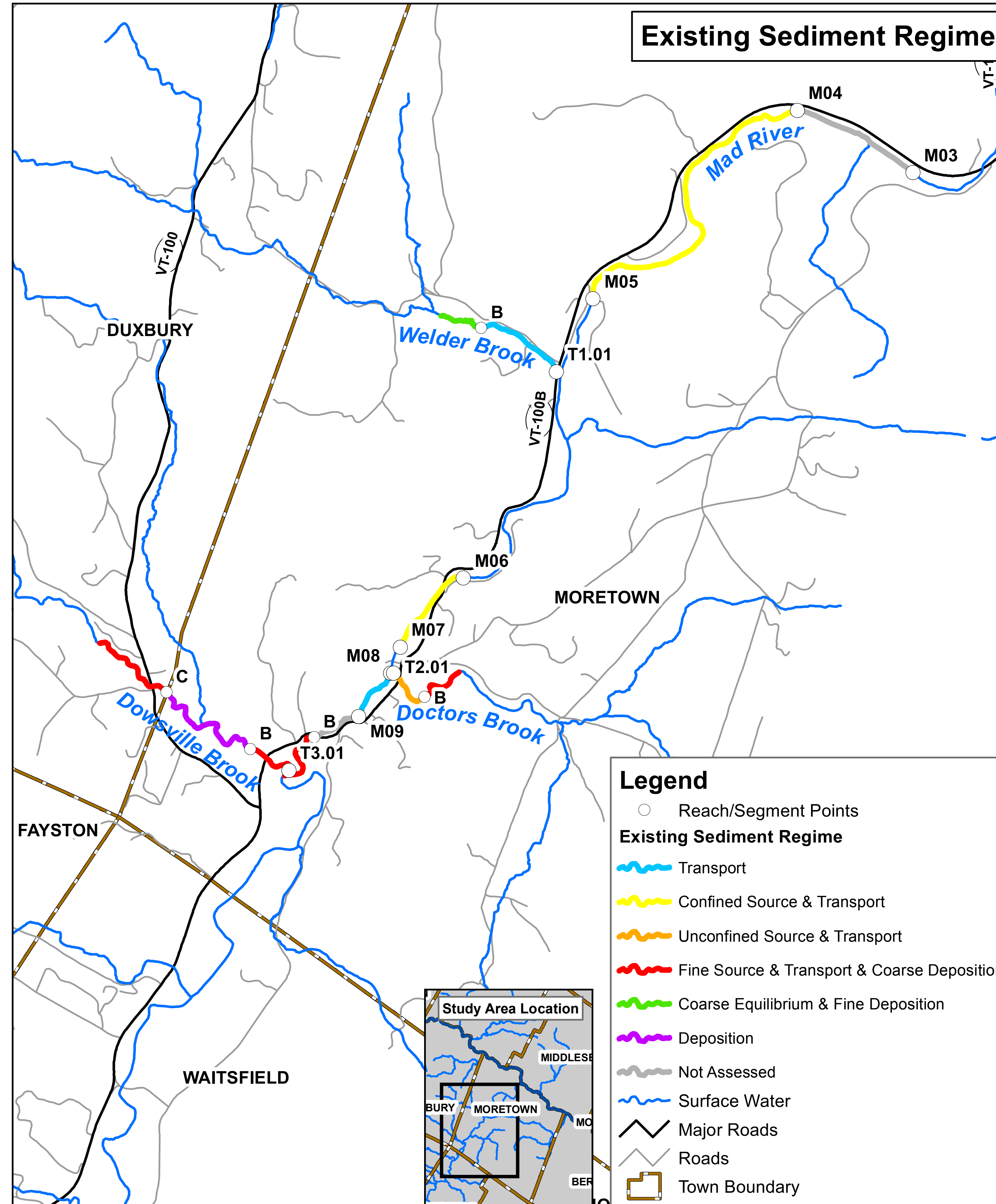




Jones Brook, Kelley Brook, & Herring Brook Stream Condition Moretown & Berlin, Vermont

Bear Creek Environmental



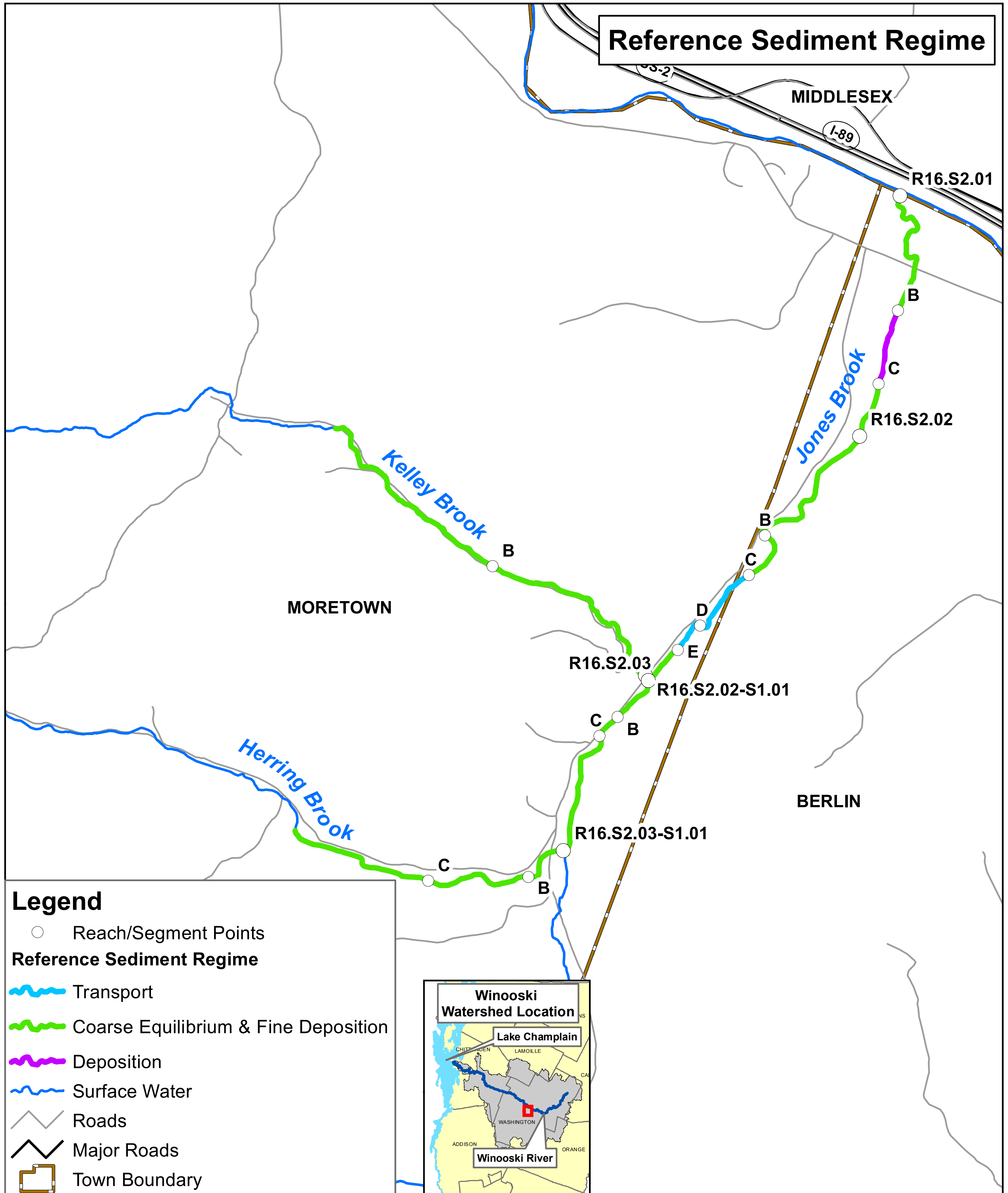


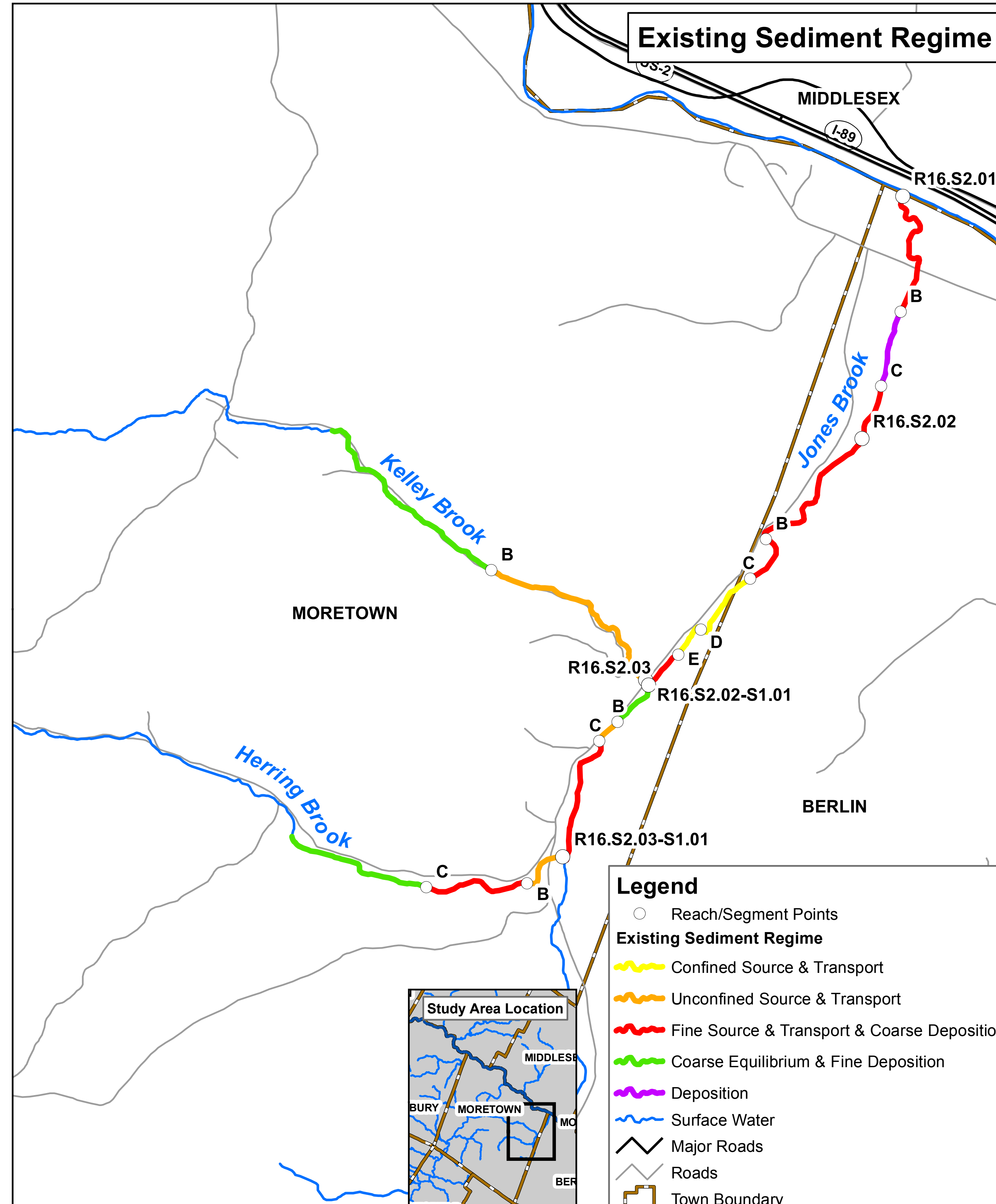
Mad River, Welder Brook, Doctors Brook, & Dowsville Brook Sediment Regime Moretown, Vermont

0 1 2 Miles

N

Bear Creek Environmental





Jones Brook, Kelley Brook,
& Herring Brook
Sediment Regime
Moretown & Berlin, Vermont

0 0.5 1 Mile

N

Bear Creek Environmental

APPENDIX B

Bridge & Culvert Assessment Data

Table 1. Scoring Table (Vermont Culvert Geomorphic Compatibility Screen Tool, adapted by BCE for bridges)				
Score	**% Bankfull Width**	**Sediment Continuity**	**Approach Angle**	**Erosion and Armoring**
5	%BFW ≥ 120	No upstream deposition or downstream bed scour	Naturally Straight	No erosion **or** armoring
4	100 ≤ %BFW < 120	**Either** upstream deposition **or** downstream bed scour, **without** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	n/a	No erosion **and** intact armoring, **or** low upstream **or** downstream erosion **without** armoring
3	75 ≤ %BFW < 100	**Either** upstream deposition **or** downstream bed scour, **with** either upstream deposits taller than 0.5 bankfull height **or** high downstream banks	Mild bend	Low upstream **or** downstream erosion **with** armoring
2	50 ≤ %BFW < 75	**Both** upstream deposition **and** downstream bed scour, **without** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	Channelized Straight	Low upstream **and** downstream erosion
1	30 ≤ %BFW < 50	**Both** upstream deposition **and** downstream bed scour, **with** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	n/a	Severe upstream **or** downstream erosion
0	%BFW < 30	**Both** upstream deposition **and** downstream bed scour, **with** upstream deposits taller than 0.5 bankfull height **and** high downstream banks	Sharp Bend	Severe upstream **and** downstream erosion, **or** failing armoring upstream **or** downstream

Table 2. Compatibility Rating Results (Vermont Culvert Geomorphic Compatibility Screen Tool, adapted by BCE for bridges)			
Category Name	**Screen Score**	**Threshold Conditions**	**Description of Structure-channel Geomorphic Compatibility**
Fully Compatible	16<GC≤20	n/a	Structure fully compatible with natural channel form and process. There is a low risk of failure. No replacement anticipated over the lifetime of the structure. A similar structure is recommended when replacement is needed.
Mostly Compatible	12<GC≤16	n/a	Structure mostly compatible with current channel form and process. There is a low risk of failure. No replacement anticipated over the lifetime of the structure. Minor design adjustments recommended when replacement is needed to make fully compatible.
Partially Compatible	8<GC≤12	n/a	Structure compatible with either current form or process, but not both. Compatibility likely short term. There is a moderate risk of structure failure and replacement may be needed. Re-design suggested to improve geomorphic compatibility.
Mostly Incompatible	4<GC≤8	% Bankfull Width + Approach Angle scores ≤ 2	Structure mostly incompatible with current form and process, with a moderate to high risk of structure failure. Re-design and replacement planning should be initiated to improve geomorphic compatibility.
Fully Incompatible	0≤GC≤4	% Bankfull Width + Approach Angle scores ≤ 2 **AND** Sediment Continuity + Erosion and Armoring scores ≤ 2	Structure fully incompatible with channel and high risk of failure. Re-design and replacement should be performed as soon as possible to improve geomorphic compatibility.

Table 3. Scoring Table **Vermont Culvert Geomorphic Compatibility Screen Tool (Milone & MacBroom, 2008)**					
Score	**% Bankfull Width**	**Sediment Continuity**	**Slope**	**Approach Angle**	**Erosion and Armoring**
5	%BFW ≥ 120	No upstream deposition or downstream bed scour	Structure slope equal to channel slope, and no break in valley slope	Naturally Straight	No erosion **or** armoring
4	100 ≤ %BFW < 120	**Either** upstream deposition **or** downstream bed scour, **without** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	n/a	n/a	No erosion **and** intact armoring, **or** low upstream **or** downstream erosion **without** armoring
3	75 ≤ %BFW < 100	**Either** upstream deposition **or** downstream bed scour, **with** either upstream deposits taller than 0.5 bankfull height **or** high downstream banks	Structure slope equal channel slope, with local break in valley slope	Mild bend	Low upstream **or** downstream erosion **with** armoring
2	50 ≤ %BFW < 75	**Both** upstream deposition **and** downstream bed scour, **without** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	Structure slope higher or lower than channel slope, and no break in valley slope	Channelized Straight	Low upstream **and** downstream erosion
1	30 ≤ %BFW < 50	**Both** upstream deposition **and** downstream bed scour, **with** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	n/a	n/a	Severe upstream **or** downstream erosion
0	%BFW < 30	**Both** upstream deposition **and** downstream bed scour, **with** upstream deposits taller than 0.5 bankfull height **and** high downstream banks	Structure slope higher or lower than channel slope, with local break in valley slope	Sharp Bend	Severe upstream **and** downstream erosion, **or** failing armoring upstream **or** downstream

Table 4. Geomorphic Compatibility Rating Results **Vermont Culvert Geomorphic Compatibility Screen Tool (Milone & MacBroom, 2008)**			
Category Name	**Screen Score**	**Threshold Conditions**	**Description of Structure-channel Geomorphic Compatibility**
Fully Compatible	20<GC≤25	n/a	Structure fully compatible with natural channel form and process. There is a low risk of failure. No replacement anticipated over the lifetime of the structure. A similar structure is recommended when replacement is needed.
Mostly Compatible	15<GC≤20	n/a	Structure mostly compatible with current channel form and process. There is a low risk of failure. No replacement anticipated over the lifetime of the structure. Minor design adjustments recommended when replacement is needed to make fully compatible.
Partially Compatible	10<GC≤15	n/a	Structure compatible with either current form or process, but not both. Compatibility likely short term. There is a moderate risk of structure failure and replacement may be needed. Re-design suggested to improve geomorphic compatibility.
Mostly Incompatible	5<GC≤10	% Bankfull Width + Approach Angle scores ≤ 2	Structure mostly incompatible with current form and process, with a moderate to high risk of structure failure. Re-design and replacement planning should be initiated to improve geomorphic compatibility.
Fully Incompatible	0≤GC≤5	% Bankfull Width + Approach Angle scores ≤ 2 **AND** Sediment Continuity + Erosion and Armoring scores ≤ 2	Structure fully incompatible with channel and high risk of failure. Re-design and replacement should be performed as soon as possible to improve geomorphic compatibility.

Table 5. Aquatic Organism Passage (AOP) Coarse Screen Tool
(Milone & MacBroom, 2009)

VT Aquatic Organism Passage Coarse Screen	**Full AOP**	**Reduced AOP**	**No AOP**			
Updated 2/25/2008	**for all aquatic organisms**	**for all aquatic organisms**	**for all aquatic organisms except adult salmonids**		**for all aquatic organisms including adult salmonids**	
AOP Function Variables / Values	**Green (if all are true)**	**Gray (if any are true)**	**Orange**		**Red**	
Culvert outlet invert type	at grade **OR** backwatered	cascade	free fall **AND**		free fall **AND**	
Outlet drop (ft)	= 0		> 0 , < 1 ft **OR**		≥ 1 ft **OR**	
Downstream pool present			= yes	(= yes **AND**	= no **OR**	(= yes **AND**
Downstream pool entrance depth / outlet drop			n/m	≥ 1)	n/a	< 1) **OR**
Water depth in culvert at outlet (ft)					< 0.3 ft	
Number of culverts at crossing	1	> 1				
Structure opening partially obstructed	= none	≠ none				
Sediment throughout structure	yes	no				

Notes:
Assessment completed during low flows
Outlet drop = invert of structure to water surface
Pool present variable is used alone if pool depths are not measured
n/m = not measured
n/a = not applicable

Table 6. Moretown Phase 2 Bridge Assessment
Geomorphic Compatibility

Reach/ Segment Number	Town	Road Name	Structure ID[1]	Percent Bankfull Channel Constriction Width[2]	Phase 2 Notes	Scoring: % Bankfull Width[3]	Scoring: Sediment Continuity	Scoring: Approach Angle	Scoring: Erosion & Armoring	Scoring: Total Score	Scoring: Geomorphic Compatibility	Priority for Replacement
M06	Moretown	Vermont Route 100B	201212000412121	180/116.7 = 154	Bridge is in good condition and appears to be a newer structure.	5	4	2	2	**13**	Mostly Compatible	Not recommended for replacement (newer structure in good condition)
T1.01-A	Moretown	Highland Drive	700000000412123	26/20.9 = 124	Bridge is built on ledge on one side.	5	4	3	2	**14**	Mostly Compatible	Not recommended for replacement (Minimal issues; not a channel constriction)
T2.01-A	Moretown	Vermont Route 100B	301212000312121	15.5/21.7 = 71	Date on bridge is 1928. Bridge is in poor condition; there is a hole from the road surface through the bridge decking, there are many cracks and stepped footers. Riprap placed on bed within structure to stabilize channel. Brook appears to have scoured under the left abutment, but was covered with riprap. Right abutment deteriorated at downstream end.	2	5	0	0	**7**	Mostly Incompatible	**High** (poor condition, undersized, alignment and scour issues)
T2.01-A	Moretown	Trail	700000000512123	16.5/21.7 = 76	Bridge washed out during Irene and clogs with LWD according to landowner.	3	2	2	0	**7**	Mostly Incompatible	Moderate (Undersized and recurring problem with clogging with debris)
T3.01-A	Moretown	Vermont Route 100B	200167000112122	25.5/30.7 = 83	Bridge is in good condition and appears to have minor issues.	3	2	2	1	**8**	Mostly Incompatible	Low (Good condition and minor issues)
T3.01-B	Moretown	Trail	700000000612123	56/30.7 = 182	Bridge appears to be used for cross country skiing and/or mountain biking. There is only one abutment. Not a channel constriction.	5	4	3	2	**14**	Mostly Compatible	Not recommended for replacement (minimal impacts; not a channel constriction)
T3.01-C	Moretown	Vermont Route 100	200013018712062	63.5/30.7 = 207	Bridge looks new. Riprap within structure within abutments.	5	4	3	0	**12**	Partially Compatible	Not recommended for replacement (Bridge looks new and is well sized)
R16.S2.01-A	Berlin	Three Mile Bridge Road	101203000412031	50/36.2 = 138	Bridge in good condition overall, but cables and decking on bridge is in poor condition. Low clearance.	5	4	2	1	**12**	Partially Compatible	Moderate (Bridge has long span but low clearance; issues with deterioration of decking)
R16.S2.02-A	Moretown	Private driveway	700000000212123	28.2/29.8 = 95	“Magliner Mobildock” bridge placed on poured cement/concrete block abutments.	3	5	2	2	**12**	Partially Compatible	Low (temporary bridge placed on concrete abutments; minimal issues)
R16.S2.03-S1.01-C	Moretown	Private driveway	700000000312123	47/25.2 = 187	Bridge looks new; no issues noted.	5	4	3	1	**14**	Mostly Compatible	Not recommended for replacement (not a channel constriction and no issues noted)

[1]The structure ID is the identification number provided by the 2010 “TransStructures_TRANSTRUC” shapefile from the Vermont Center for Geographic Information, unless no number was available. In this case, the SGAID is provided.
[2]Percent Bankfull Channel Width percentages are calculated based on the reference channel width for each reach. The percentage is calculated by dividing the present constriction width by the reference channel width.
[3]The % bankfull width is based on the constriction calculation.

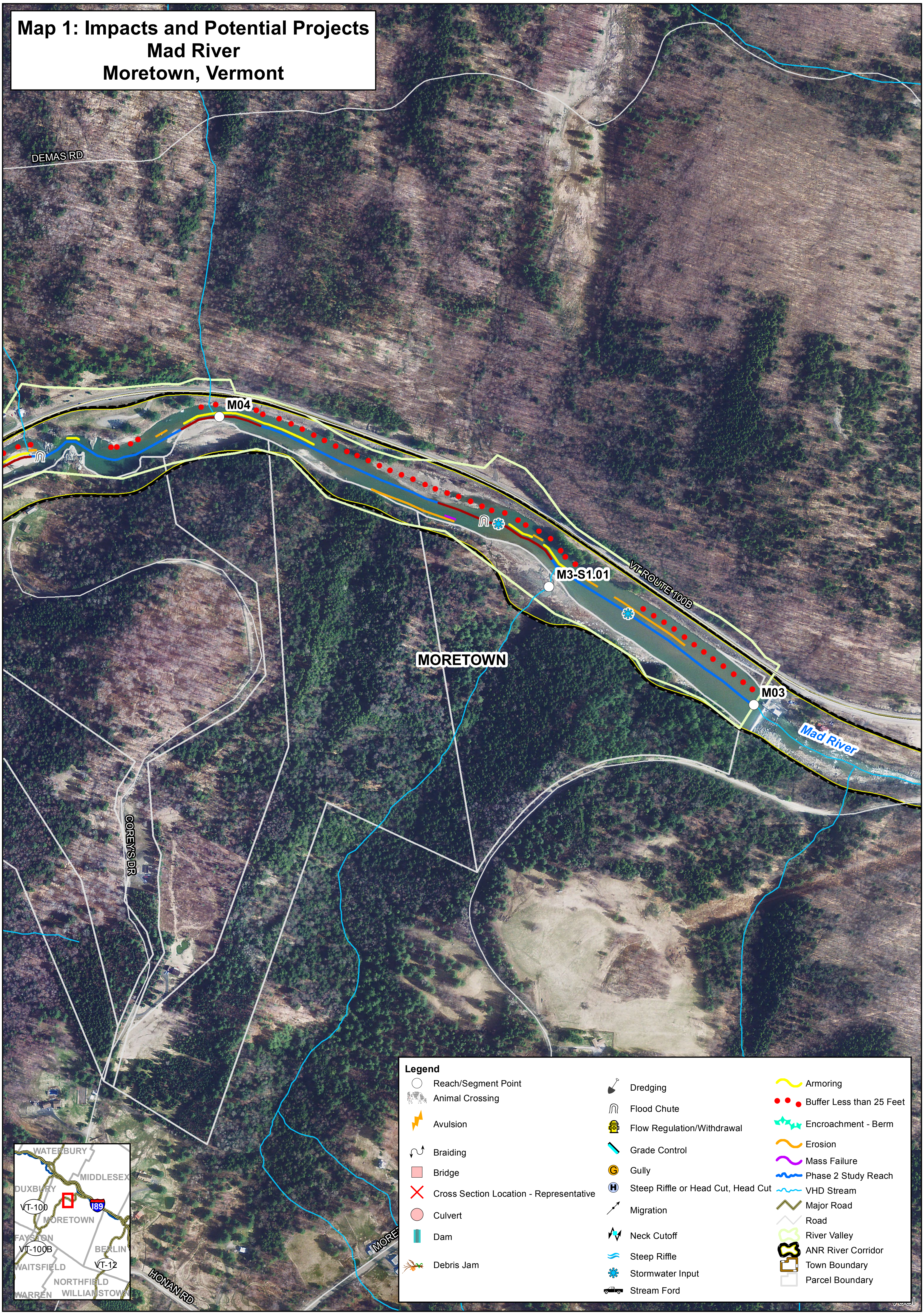
Table 7. Moretown Phase 2 Culvert Assessment
Geomorphic Compatibility and Aquatic Organism Passage (AOP)

Reach/ Segment Number	Road Name	Structure Type and ID[1]	Percent Bankfull Channel Width[2]	Phase 2 Notes	Scoring (Geomorphic Compatibility - Milone & MacBroom, 2008; AOP – Milone & MacBroom, 2009)								Priority for Replacement
					% Bankfull Width	Sediment Continuity	Slope	Approach Angle	Erosion & Armoring	Total Score	Geomorphic Compatibility	AOP	
T1.01-A	Vermont Route 100B	30016700512121[3]	13.2/20.9 = 63	Culvert empties directly into the Mad River and has a free fall outlet at low flows.	2	1	5	0	1	**9**	Mostly Incompatible	Reduced AOP	Moderate (undersized, free fall outlet at low flows, beginning to rust)
R16.S2.02-S1.01-A	Jones Brook Road	100000000612121	8/18.2 = 44	Concrete box culvert in good condition.	1	4	2	2	0	**9**	Mostly Incompatible	Reduced AOP	Moderate (significantly undersized but in good condition overall)
R16.S2.02-S1.01-A	Ward Brook Road	40121002312121[3]	16.2/18.2 = 89	Newer concrete box culvert with bed retention sills.	3	2	5	3	5	**18**	Mostly Compatible	Reduced AOP	Not recommended for replacement (new and minimal issues)
R16.S2.02-S1.01-A	Private driveway	70001702621212x[3]	7.2/18.2 = 40	Listed in the DMS as being on Ward Brook Road but is actually driveway to 360 Ward Brook Road. Steel corrugated pipe is rusting.	1	2	5	2	0	**10**	Mostly Incompatible	Reduced AOP	Moderate (undersized with failing riprap)
R16.S2.02-S1.01-B	Ward Brook Road	401212002812121[3]	12/18.2 = 66	New concrete box culvert with bed retention sills.	2	5	5	0	4	**16**	Mostly Compatible	Reduced AOP	Not recommended for replacement (new structure)
R16.S2.02-S1.01-B	Ward Brook Road	401212000612121[3]	5.8/18.2 = 32	Outlet is a free fall onto a riprap cascade. Rusting steel corrugated pipe.	1	2	5	3	3	**14**	Partially Compatible	No AOP Including Adult Salmonids	**High** (large free fall, evident scour issues at outlet, rusting, significantly undersized)
R16.S2.02-S1.01-B	Ward Brook Road	401212000712121[3]	6.3/18.2 = 35	Steel corrugated culvert with free fall at outlet.	1	1	5	5	2	**14**	Partially Compatible	No AOP Including Adult Salmonids	**High** (free fall outlet, significantly undersized)
R16.S2.03-S1.01-A	Jones Brook Road	401212002912121[3]	10.8/25.2 = 43	Steel corrugated culvert	1	4	5	3	0	**13**	Partially Compatible	No AOP Except Adult Salmonids	Moderate (undersized with small free fall at outlet)

[1]The structure ID is the identification number provided by the 2010 "TransStructures_TRANSTRUC" shapefile from the Vermont Center for Geographic Information, unless no number was available. In this case the SGAID is provided.
[2]Percent Bankfull Channel Width percentages are calculated based on the reference channel width for each reach. The percentage is calculated by dividing the culvert width by the reference channel width.
[3]Culvert was assessed in either 2006 or 2013 as part of a larger culvert assessment project. Data for these structures were not collected by Bear Creek Environmental.

APPENDIX C

Potential Project Locations & Descriptions



Data sources include:
Vermont Agency of Natural Resources
Vermont Center for Geographic Information
Central Vermont Regional Planning Commission
Bear Creek Environmental

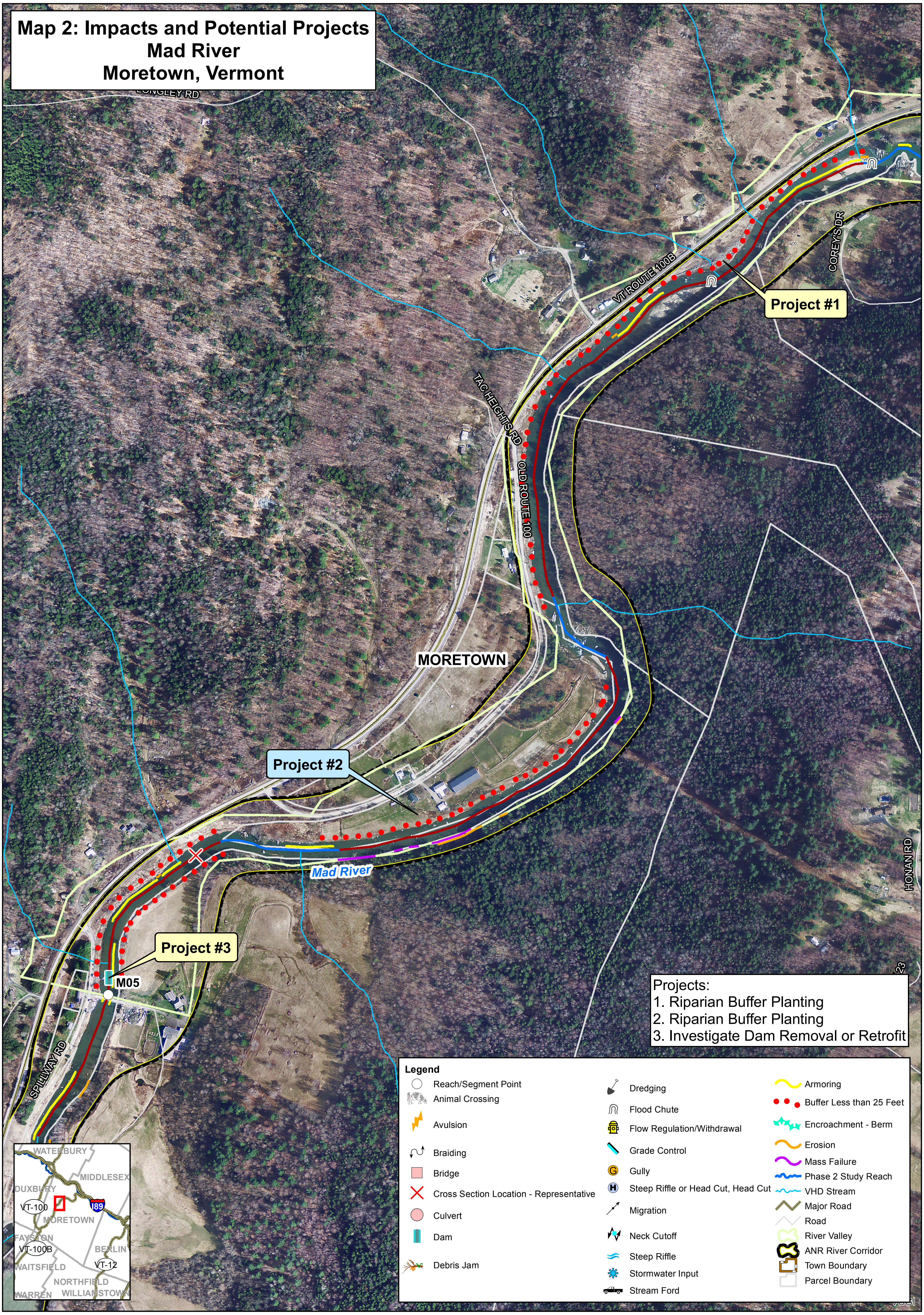
N

1 inch = 500 feet

0 500 1,000 Feet

Bear Creek Environmental

Map 2: Impacts and Potential Projects
Mad River
Moretown, Vermont



Data sources include:
Vermont Agency of Natural Resources
Vermont Center for Geographic Information
Central Vermont Regional Planning Commission
Bear Creek Environmental

Map composed on 1/26/18. Revised on 4/17/18.

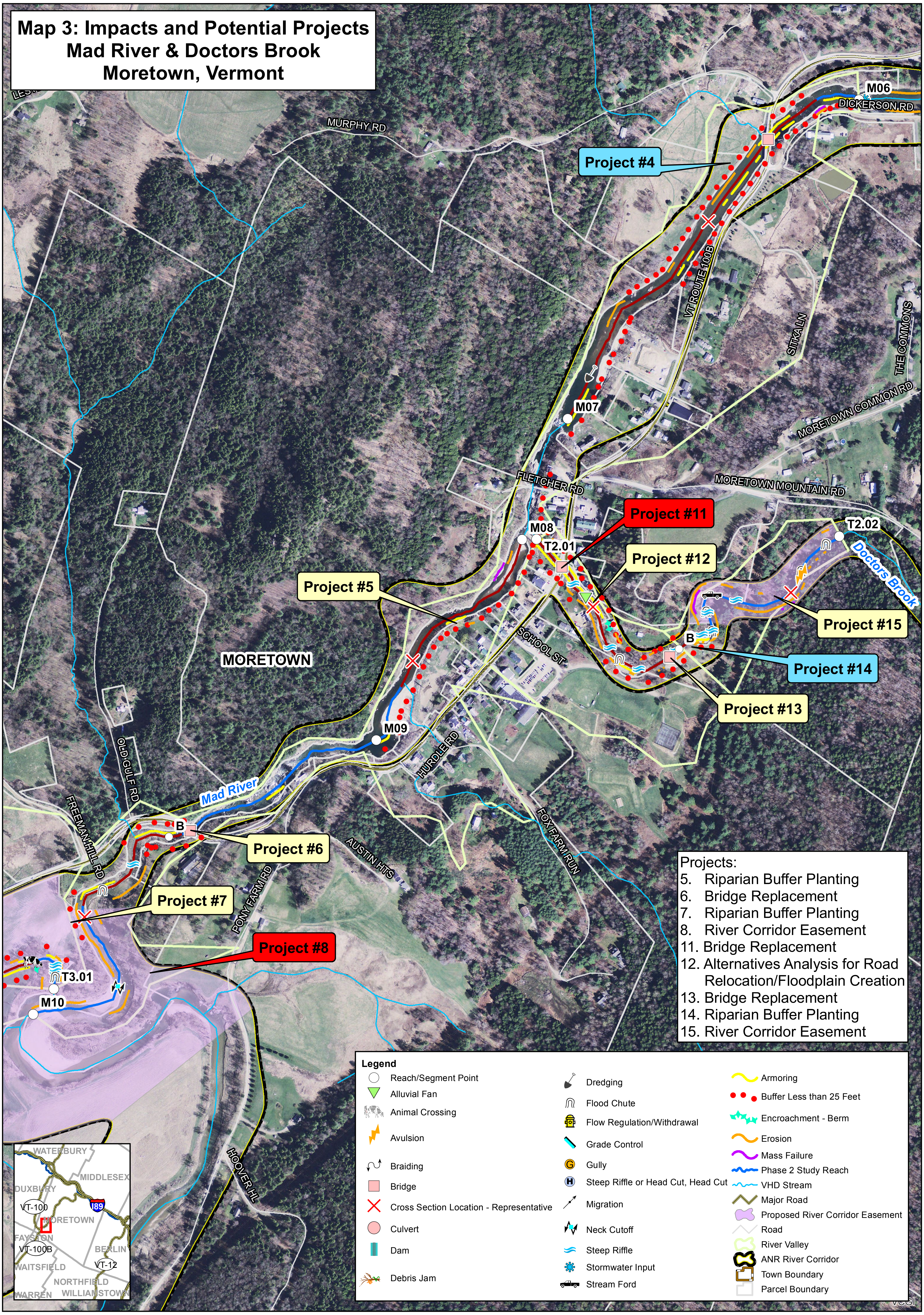
Project Priority:
- Low
- Moderate
- High

N

1 inch = 500 feet

0 500 1,000 Feet

Bear Creek Environmental



Data sources include:
Vermont Agency of Natural Resources
Vermont Center for Geographic Information
Central Vermont Regional Planning Commission
Bear Creek Environmental

Map composed on 1/26/18. Revised on 4/17/18.

Project Priority:
Low
Moderate
High

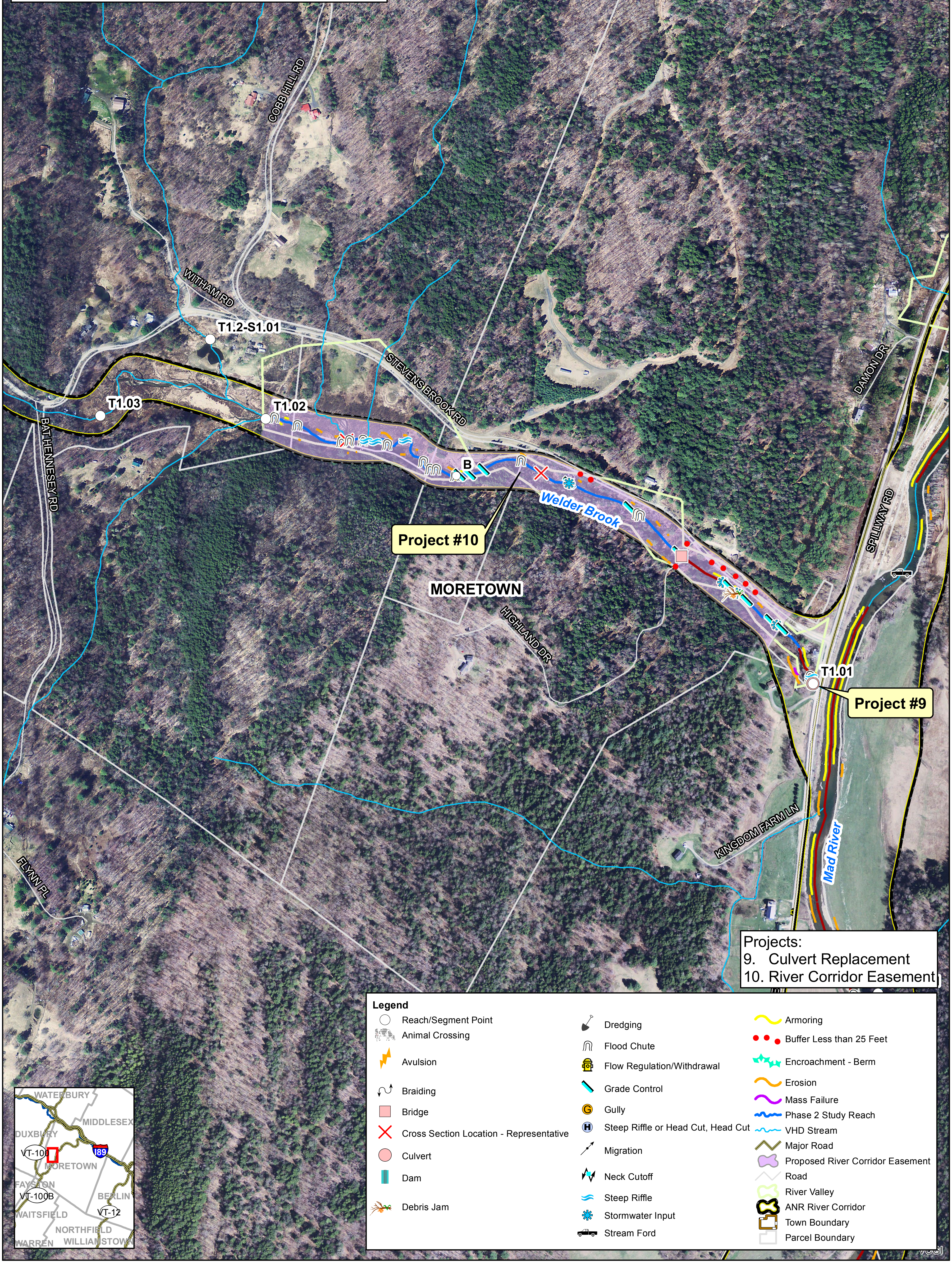
N

1 inch = 500 feet

0 500 1,000 Feet

Bear Creek Environmental

Map 4: Impacts and Potential Projects
Welder Brook
Moretown, Vermont



Data sources include:
Vermont Agency of Natural Resources
Vermont Center for Geographic Information
Central Vermont Regional Planning Commission
Bear Creek Environmental

Map composed on 1/26/18. Revised on 4/17/18.

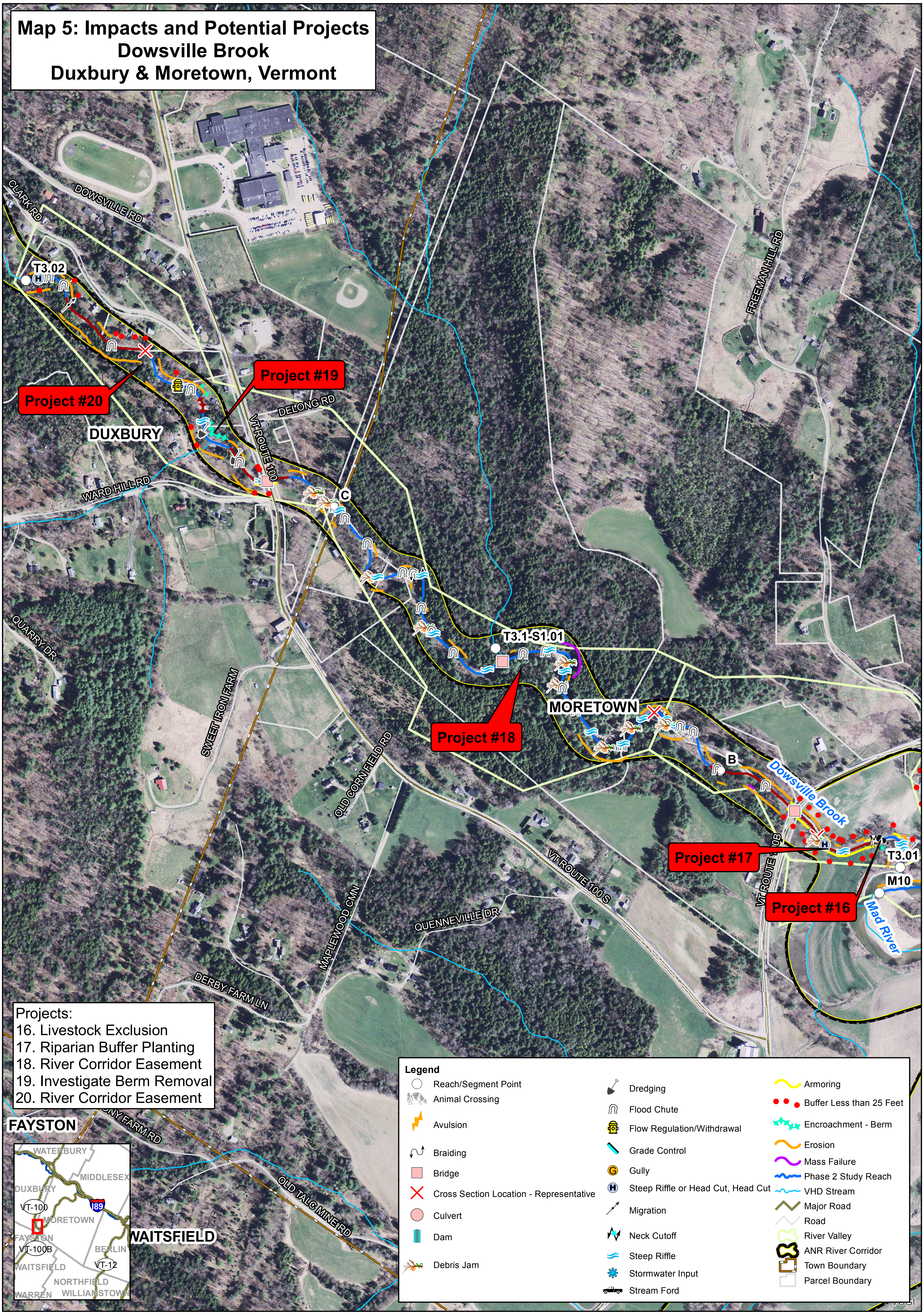
Project Priority:
- Low
- Moderate
- High

N

1 inch = 500 feet

0 500 1,000 Feet

Bear Creek Environmental



Data sources include:
Vermont Agency of Natural Resources
Vermont Center for Geographic Information
Central Vermont Regional Planning Commission
Bear Creek Environmental

Map composed on 1/26/18. Revised on 4/17/18.

Project Priority:
- Low
- Moderate
- High

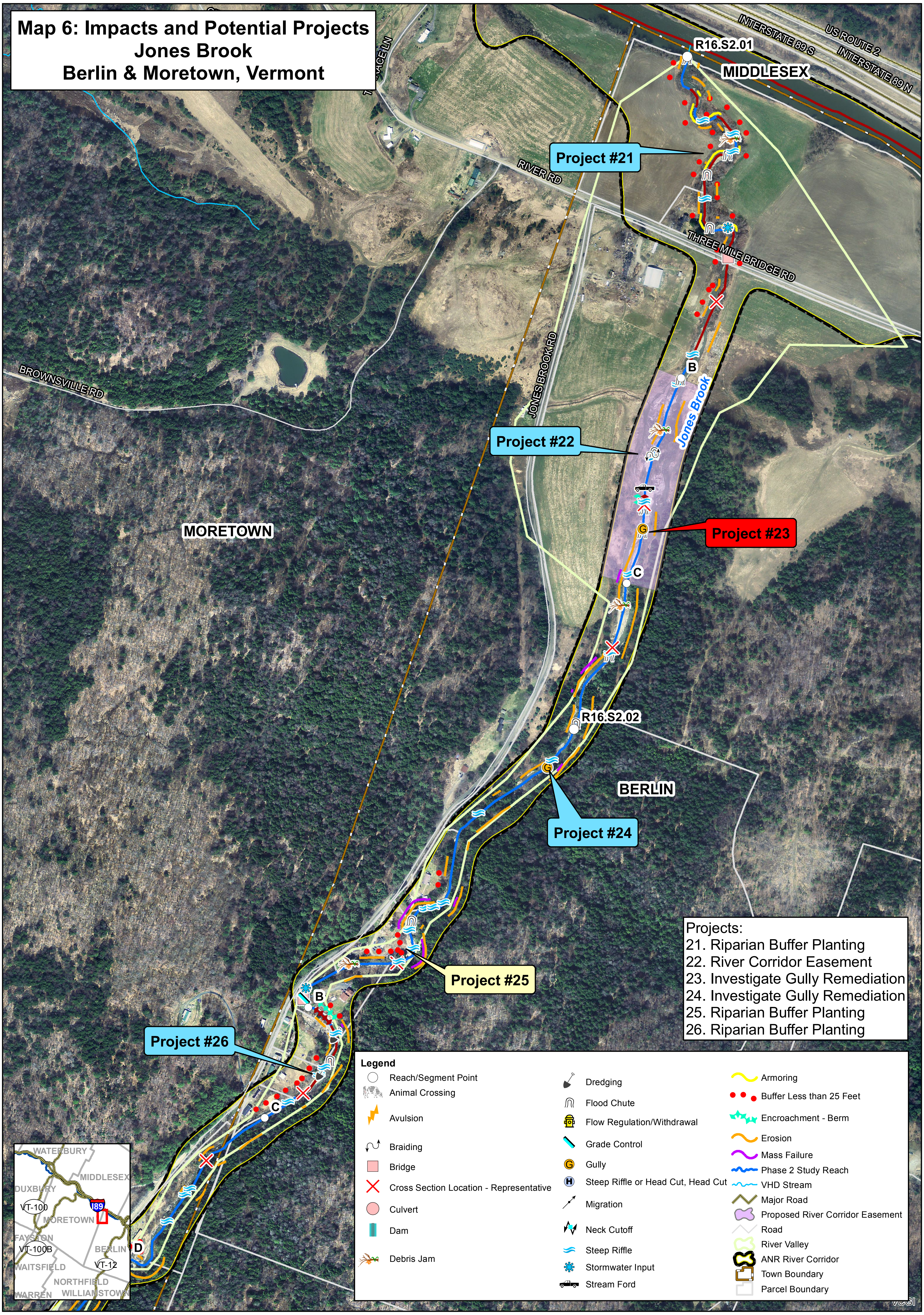
N

1 inch = 500 feet

0 500 1,000 Feet

Bear Creek Environmental

Map 6: Impacts and Potential Projects
Jones Brook
Berlin & Moretown, Vermont



Data sources include:
Vermont Agency of Natural Resources
Vermont Center for Geographic Information
Central Vermont Regional Planning Commission
Bear Creek Environmental

Map composed on 1/26/18. Revised on 4/17/18.

Project Priority:
- Low
- Moderate
- High

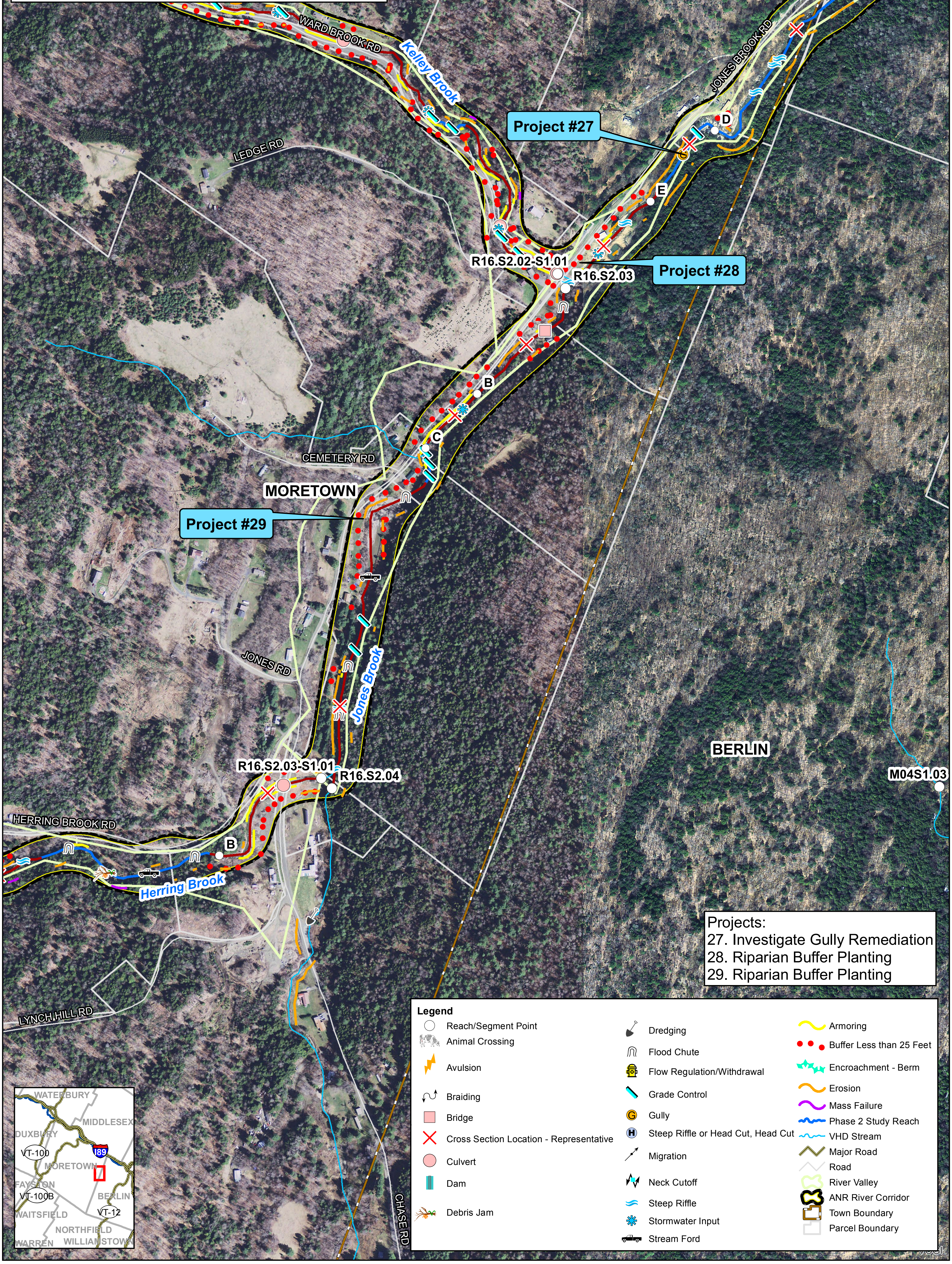
N

1 inch = 500 feet

0 500 1,000 Feet

Bear Creek Environmental

Map 7: Impacts and Potential Projects
Jones Brook
Moretown, Vermont



Data sources include:
Vermont Agency of Natural Resources
Vermont Center for Geographic Information
Central Vermont Regional Planning Commission
Bear Creek Environmental

Map composed on 1/26/18. Revised on 4/17/18.

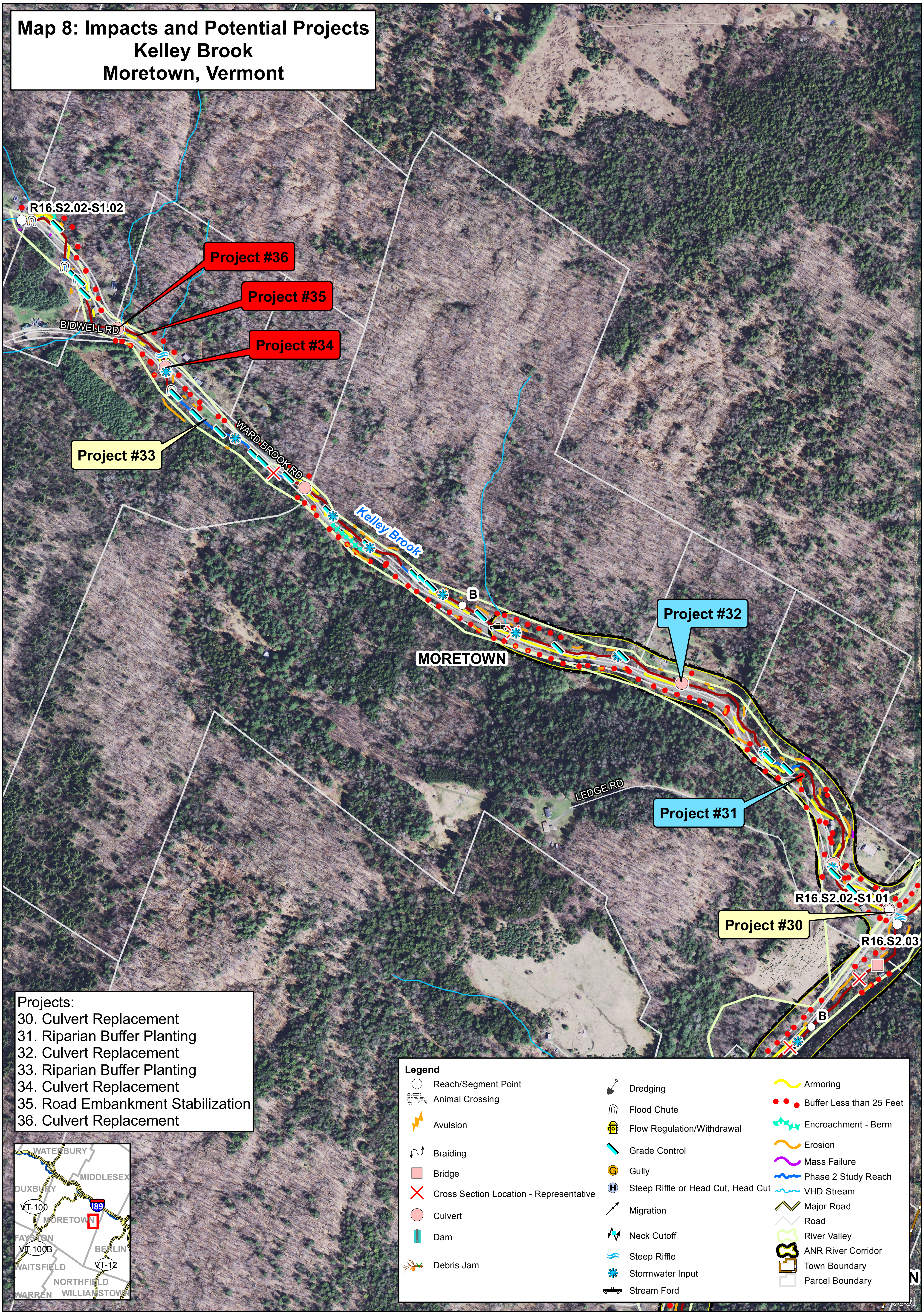
Project Priority:
- Low
- Moderate
- High

N

1 inch = 500 feet

0 500 1,000 Feet

Bear Creek Environmental



Data sources include:
Vermont Agency of Natural Resources
Vermont Center for Geographic Information
Central Vermont Regional Planning Commission
Bear Creek Environmental

Map composed on 1/26/18. Revised on 4/17/18.

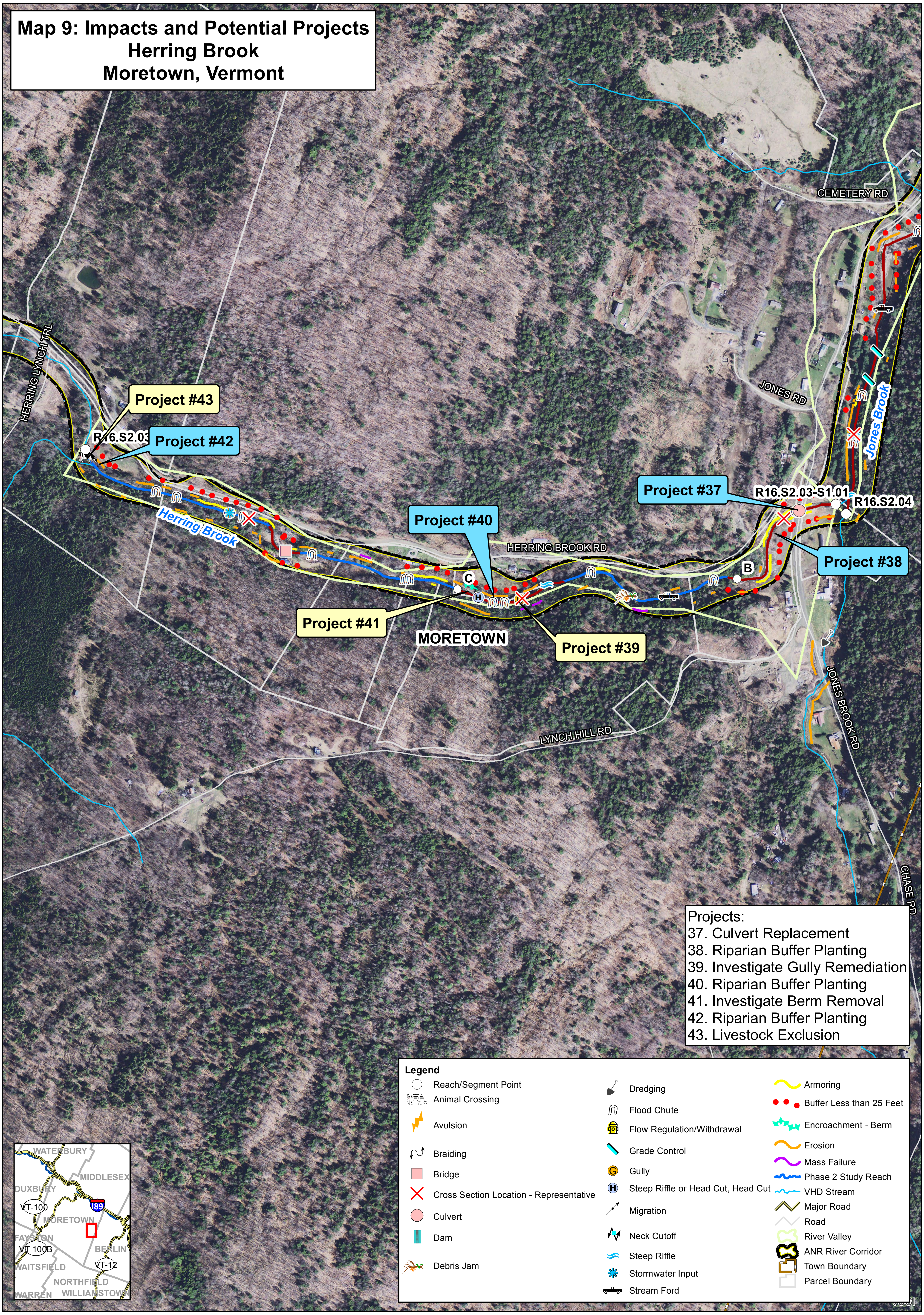
Project Priority:
- Low
- Moderate
- High

N

1 inch = 500 feet

0 500 1,000 Feet

Bear Creek Environmental



Data sources include:
Vermont Agency of Natural Resources
Vermont Center for Geographic Information
Central Vermont Regional Planning Commission
Bear Creek Environmental

Map composed on 1/26/18. Revised on 4/17/18.

Project Priority:
Low
Moderate
High

N

1 inch = 500 feet

0 500 1,000 Feet

Bear Creek Environmental

BCE Project ID	BCE Map Number	ProjectName	ProjectDescription	ProjectType	ProjectTypeID	SGA reach	Latitude	Longitude	Notes	Towns	SubBasin	Priority	Potential Partners
1	2	Buffer planting in reach M04 of the Mad River	Plant native trees and shrubs along roughly 600 feet of the western river bank across Route 100B from 4485 VT Route 100B.	River - Planting	5	M04	44.288304	-72.72908		Moretown	Mad River	Low	Friends of the Mad River, Landowner(s)
2	2	Buffer planting at horse farm in M04	Plant native trees and shrubs along 2000 feet of the Mad River where buffer is lacking due to clearing at horse farm.	River - Planting	5	M04	44.279616	-72.7356		Moretown	Mad River	Moderate	Friends of the Mad River, Landowner(s)
3	2	Investigate dam removal or retrofit at Bridge Road in Moretown	There is an old ~4.5 foot concrete dam just downstream of the Bridge Road Bridge on the Mad River in Moretown. The dam appears to be associated with a USGS gaging station and likely creates a barrier for AOP.	Dam Removal - Preliminary Design	38	M04	44.277134	-72.74233		Moretown	Mad River	Low	US Geological Survey, Vermont Fish & Wildlife Department, Friends of the Mad River
4	3	Buffer planting at pasture in M06	Riparian buffer is lacking due to the presence of pasture land for roughly 1,000 feet along the Mad River. Plant native trees and shrubs to regenerate buffer.	River - Planting	5	M06	44.255839	-72.757953		Moretown	Mad River	Moderate	Friends of the Mad River, Landowner(s)
5	3	Buffer planting in Moretown village on reach M08	Riparian buffer is lacking due to the presence of lawns behind several homes in Moretown village. Plant native trees and shrubs along roughly 1,400 feet of river bank on up to 8 properties.	River - Planting	5	M08	44.248658	-72.763818	Multiple landowners	Moretown	Mad River	Low	Friends of the Mad River, Landowner(s)
6	3	Replace VT Route 100B Bridge near Old Gulf Road	Replace bridge on Route 100B. It appears to be very old and in poor condition.	Floodplain/Stream Restoration - Preliminary Design	6	M09-A	44.245452	-72.769591	Construction work was occurring in the vicinity of the bridge during the Phase 2 SGA field work. Unknown whether construction activities were being performed on the bridge or just roadway nearby. Bridge does not appear to be a geomorphic compatibility issue.	Moretown	Mad River	Low	Vermont Agency of Transportation, Town of Moretown, Central Vermont Regional Planning Commission
7	3	Buffer planting on agricultural field in M09	Riparian buffer is lacking along an agricultural field. Plant native trees and shrubs along ~250 feet of the river to restore the buffer.	River - Planting	5	M09-B	44.24402	-72.772162		Moretown	Mad River	Low	Friends of the Mad River, Landowner(s)
8	3	River corridor easement at upstream end of M09-B	The Mad River is adjusting laterally in upper M09-B, which includes changes in sinuosity and a pending neck cutoff. Protect this area through a river corridor easement and prevent future channel management.	River Corridor Easement - Design	57	M09-B	44.243224	-72.770438	Landowners have indicated concern about the river and its adjustments on their property. Could be pursued in conjunction with potential river corridor easements on mid and upper Dowsville Brook (Projects #18 & 20).	Moretown	Mad River	High	Friends of the Mad River, Vermont Land Trust, Vermont River Conservancy, Landowner(s)
9	4	Culvert replacement on Route 100B in T1.01	Culvert is severely undersized, rusting out, and has a slight free fall outlet drop to the Mad River under low flow conditions (possible AOP issue).	Floodplain/Stream Restoration - Preliminary Design	6	T1.01-A	44.271582	-72.745848	Culvert is technically located just downstream of the reach break due to reach break not aligning with confluence	Moretown	Lower Mad River Tributaries	Low	Vermont Agency of Transportation, Town of Moretown, Central Vermont Regional Planning Commission
10	4	River corridor easement on T1.01	Lower portion of reach is very stable section of Welder Brook with nice habitat. Upper portion of reach is dynamic wetland complex where abundant planform change is evident. Two large parcels along roughly 3,700 feet of stream length. Could be protected through river corridor easement.	River Corridor Easement - Design	57	T1.01	44.274831	-72.752136		Moretown	Lower Mad River Tributaries	Low	Friends of the Mad River, Vermont Land Trust, Vermont River Conservancy, Landowner(s)
11	3	Replace VT Route 100B Bridge on Doctors Brook	Undersized, poorly aligned bridge in poor condition	Floodplain/Stream Restoration - Preliminary Design	6	T2.01-A	44.249566	-72.761584	Bridge is in poor condition, has scour issues, and is undersized. According to CVRPC, the bridge catches debris during flooding.	Moretown	Lower Mad River Tributaries	High	Vermont Agency of Transportation, Town of Moretown, Central Vermont Regional Planning Commission
12	3	Alternatives analysis for relocation/removal of Doctors Brook Road and floodplain creation	Evaluate options to possibly relocate or remove Doctors Brook Road and replace the road with a small floodplain bench.	Floodplain/Stream Restoration - Preliminary Design	6	T2.01-A	44.24902	-72.760892	Doctors Brook Road is a major channel encroachment and according to CVRPC it frequently receives damage from the brook.	Moretown	Lower Mad River Tributaries	Low	Town of Moretown, Central Vermont Regional Planning Commission

BCE Project ID	BCE Map Number	ProjectName	ProjectDescription	ProjectType	ProjectTypeID	SGA reach	Latitude	Longitude	Notes	Towns	SubBasin	Priority	Potential Partners
13	3	Replace private bridge on Doctors Brook	Replace undersized private bridge on Doctors Brook	Floodplain/Stream Restoration - Preliminary Design	6	T2.01-A	44.248174	-72.759252	According to landowner, bridge washed out during Irene and clogs with LWD. Rebuilt bridge following Irene and installed it 3 feet higher than it was previously.	Moretown	Lower Mad River Tributaries	Low	Central Vermont Regional Planning Commission, Landowner(s)
14	3	Buffer planting along Doctors Brook	Plant native trees and shrubs along 400-500 feet of the brook where vegetation is lacking due to residential land use	River - Planting	5	T2.01	44.24833	-72.758777		Moretown	Lower Mad River Tributaries	Moderate	Friends of the Mad River, Landowner(s)
15	3	River corridor easement along Doctors Brook	River corridor easement along T2.01-B. One large parcel. Corridor is forested; dynamic section of the brook with channel avulsion and mass failures.	River Corridor Easement - Design	57	T2.01-B	44.249131	-72.757024	Protect the upper watershed of Doctors Brook from future development through an easement.	Moretown	Lower Mad River Tributaries	Low	Friends of the Mad River, Vermont Land Trust, Vermont River Conservancy, Landowner(s)
16	5	Livestock exclusion on Dowsville Brook	Animal access point from cow pasture to brook. Investigate livestock exclusion/other options for a water source to improve water quality.	Agricultural Pollution Prevention - Preliminary Design	65	T3.01-A	44.24341	-72.772945		Moretown	Lower Mad River Tributaries	High	Natural Resources Conservation Service, US Fish & Wildlife Service, Friends of the Mad River, Landowner(s)
17	5	Buffer planting in pasture along Dowsville Brook	Riparian buffer is lacking along ~550 feet of Dowsville Brook on both sides of the brook due to pasture and hay field. Plant native trees and shrubs to regenerate or at a minimum, create a setback for mowing.	River - Planting	5	T3.01-A	44.243276	-72.774052		Moretown	Lower Mad River Tributaries	High	Friends of the Mad River, Landowner(s)
18	5	River corridor easement on Dowsville Brook	River corridor easement suggested for segment T3.01-B on Dowsville Brook. Extremely dynamic segment with abundant adjustment.	River Corridor Easement - Design	57	T3.01-B	44.246054	-72.78072	Corridor is currently forested in this segment; protecting with an easement could prevent any development. Land ownership is primarily four large parcels. Could be pursued in conjunction with potential corridor easement on reach M09 of the Mad River (Project #8) and potential corridor easement on upper Dowsville Brook (Project #20).	Moretown	Lower Mad River Tributaries	High	Friends of the Mad River, Vermont Land Trust, Vermont River Conservancy, Landowner(s)
19	5	Investigate berm removal on Dowsville Brook	There is a ~200 foot long and 8 foot tall berm on the eastern bank of the brook on a forested floodplain. It could be removed to open up the forested floodplain to floodwaters.	Floodplain/Stream Restoration - Preliminary Design	6	T3.01-C	44.249598	-72.787508	Water may flow behind the berm during high flow events according to landowner correspondence.	Duxbury	Lower Mad River Tributaries	High	Central Vermont Regional Planning Commission, Friends of the Mad River, Landowner(s)
20	5	River corridor easement on upper Dowsville Brook	Lots of active adjustment is occurring in T3.01-C (aggradation and planform change mainly). Riparian corridor is well forested on western side of the brook. Recent and historic channel management are evident (dredging, berming, etc.). Protecting the river corridor could prevent future channel alterations and all for channel restoration.	River Corridor Easement - Design	57	T3.01-C	44.250774	-72.788923	Corridor on west side of the brook is one large parcel for the entire segment. Landowner indicated in phone correspondence that he has frequent conflicts with the brook. Historic and recent berms present, as well as dredging.	Duxbury	Lower Mad River Tributaries	High	Friends of the Mad River, Vermont Land Trust, Vermont River Conservancy, Landowner(s)
21	6	Buffer planting in agricultural fields along R16.S2.01-A	Riparian buffer is lacking on both sides of brook for most of segment. Abundant erosion and riprap; planting could help stabilize banks.	River - Planting	5	R16.S2.01-A	44.269982	-72.637569	Landowner expressed concern via phone correspondence about people being on his property for the Phase 2 assessment because he did not want his crop fields damaged. May not be willing to lose any crop land for buffer improvements.	Berlin	Tributaries to Upper Mid-Winooski	Moderate	Winooski Natural Resources Conservation District, Friends of the Winooski River, Landowner(s)
22	6	River corridor easement on lower Jones Brook	Protect the river corridor from future development and the channel from future management activities in a very dynamic section (braided, multiple channels).	River Corridor Easement - Design	57	R16.S2.01-B	44.265294	-72.63898	One large parcel.	Berlin	Tributaries to Upper Mid-Winooski	Moderate	Winooski Natural Resources Conservation District, Friends of the Winooski River, Vermont Land Trust, Vermont River Conservancy, Landowner(s)

BCE Project ID	BCE Map Number	ProjectName	ProjectDescription	ProjectType	ProjectTypeID	SGA reach	Latitude	Longitude	Notes	Towns	SubBasin	Priority	Potential Partners
23	6	Investigate gully remediation in R16.S2.01-B	Investigate remediation of a large gully coming off the east valley wall. Appears to be a major source of sediment to Jones Brook.	Floodplain/Stream Restoration - Preliminary Design	6	R16.S2.01-B	44.264098	-72.638737	Source of gully is unknown.	Berlin	Tributaries to Upper Mid-Winooski	High	Central Vermont Regional Planning Commission, Winooski Natural Resources Conservation District, Friends of the Winooski River, Landowner(s)
24	6	Investigate gully remediation in R16.S2.02-A	Investigate remediation of gully coming off the east valley wall.	Floodplain/Stream Restoration - Preliminary Design	6	R16.S2.02-A	44.260399	-72.640897	Source of gully is unknown. Possibly related to logging higher up in elevation.	Berlin	Tributaries to Upper Mid-Winooski	Moderate	Central Vermont Regional Planning Commission, Winooski Natural Resources Conservation District, Friends of the Winooski River, Landowner(s)
25	6	Buffer planting in R16.S2.02-A	Plant native trees and shrubs along ~500 feet of the western bank of the brook in the vicinity of 807 Jones Brook Road where buffer vegetation is lacking due to lawn.	River - Planting	5	R16.S2.02-A	44.257623	-72.643984	Site would benefit from establishment of a "no mow" zone at a minimum.	Berlin	Tributaries to Upper Mid-Winooski	Low	Winooski Natural Resources Conservation District, Friends of the Winooski River, Landowner(s)
26	6	Buffer planting in R16.S2.02-B	Plant native trees and shrubs along ~500 feet of the western bank of the brook in the vicinity of 987, 1037, & 1061 Jones Brook Road where buffer vegetation is lacking due to lawns.	River - Planting	5	R16.S2.02-B	44.255682	-72.645988	Site would benefit from establishment of a "no mow" zone at a minimum.	Berlin	Tributaries to Upper Mid-Winooski	Moderate	Winooski Natural Resources Conservation District, Friends of the Winooski River, Landowner(s)
27	7	Investigate gully remediation in R16.S2.02-D	Investigate remediation of gully coming off the east valley wall.	Floodplain/Stream Restoration - Preliminary Design	6	R16.S2.02-A	44.252415	-72.650627	Source of gully is unknown.	Moretown	Tributaries to Upper Mid-Winooski	Moderate	Central Vermont Regional Planning Commission, Winooski Natural Resources Conservation District, Friends of the Winooski River, Landowner(s)
28	7	Buffer planting in R16.S2.02-E & R16.S2.03-A	Plant native trees and shrubs along ~1200 feet of the western bank of the brook in the vicinity of the confluence with Kelley Brook where buffer vegetation is lacking.	River - Planting	5	R16.S2.02-E & R16.S2.03-A	44.250765	-72.652799	Site would benefit from establishment of a "no mow" zone at a minimum.	Moretown	Tributaries to Upper Mid-Winooski	Moderate	Winooski Natural Resources Conservation District, Friends of the Winooski River, Landowner(s)
29	7	Buffer planting in R16.S2.03-C	Plant native trees and shrubs along ~1000 feet of the western bank of the brook in the vicinity of 1789 & 1927 Jones Brook Road where buffer vegetation is lacking due to lawns.	River - Planting	5	R16.S2.03-C	44.246944	-72.657331	Site would benefit from establishment of a "no mow" zone at a minimum.	Moretown	Tributaries to Upper Mid-Winooski	Moderate	Winooski Natural Resources Conservation District, Friends of the Winooski River, Landowner(s)
30	8	Culvert replacement - Kelley Brook crossing on Jones Brook Road	Replace undersized culvert with properly sized structure.	Floodplain/Stream Restoration - Preliminary Design	6	R16.S2.02-S1.01-A	44.250609	-72.653232	Culvert appears to be in good condition structurally, but is significantly undersized.	Moretown	Tributaries to Upper Mid-Winooski	Low	Town of Moretown, Central Vermont Regional Planning Commission
31	8	Buffer planting in R16.S2.02-S1.01-A	Plant native trees and shrubs along ~600 feet of the western bank of the brook in the vicinity of 122 Ward Brook Road where buffer vegetation is lacking due to lawn.	River - Planting	5	R16.S2.02-S1.01-A	44.252741	-72.655145	Landowner indicated tentative interest in planting.	Moretown	Tributaries to Upper Mid-Winooski	Moderate	Winooski Natural Resources Conservation District, Friends of the Winooski River, Landowner(s)
32	8	Culvert replacement - driveway culvert in R16.S2.02-S1.01-A	Replace undersized culvert with properly sized structure.	Floodplain/Stream Restoration - Preliminary Design	6	R16.S2.02-S1.01-A	44.254147	-72.65779	Culvert is undersized and armoring around structure is failing.	Moretown	Tributaries to Upper Mid-Winooski	Moderate	Landowner(s), Central Vermont Regional Planning Commission
33	8	Buffer planting in R16.S2.02-S1.01-B	Plant native trees and shrubs along ~400 feet of the northern bank of the brook where buffer vegetation is lacking due to lawn/garden area.	River - Planting	5	R16.S2.02-S1.01-B	44.25825	-72.668052		Moretown	Tributaries to Upper Mid-Winooski	Low	Winooski Natural Resources Conservation District, Friends of the Winooski River, Landowner(s)
34	8	Culvert replacement - Ward Brook Road near 990 Ward Brook Road	Culvert is undersized, rusting, and an AOP issue.	Floodplain/Stream Restoration - Preliminary Design	6	R16.S2.02-S1.01-B	44.259042	-72.66896	Significantly undersized, major scour at outlet, free fall outlet.	Moretown	Tributaries to Upper Mid-Winooski	High	Town of Moretown, Central Vermont Regional Planning Commission
35	8	Stabilize road embankments along Ward Brook Road	There are several areas along R16.S2.02-S1.01 where the road embankment for Ward Brook Road is being eroded by Kelley Brook and the road is at risk of washing out.	Floodplain/Stream Restoration - Preliminary Design	6	R16.S2.02-S1.01	44.259539	-72.66957	Multiple locations of instability along Ward Brook Road (not just at location of lat/long for this project).	Moretown	Tributaries to Upper Mid-Winooski	High	Town of Moretown, Central Vermont Regional Planning Commission
36	8	Culvert replacement - Ward Brook Road near Bidwell Road intersection	Culvert is undersized and likely an AOP issue. Replace with appropriately sized structure that accommodates AOP.	Floodplain/Stream Restoration - Preliminary Design	6	R16.S2.02-S1.01-B	44.259639	-72.669991		Moretown	Tributaries to Upper Mid-Winooski	High	Town of Moretown, Central Vermont Regional Planning Commission

BCE Project ID	BCE Map Number	ProjectName	ProjectDescription	ProjectType	ProjectTypeID	SGA reach	Latitude	Longitude	Notes	Towns	SubBasin	Priority	Potential Partners
37	9	Culvert replacement - Jones Brook Road crossing over Herring Brook	Culvert is undersized and has a small free fall at the outlet.	Floodplain/Stream Restoration - Preliminary Design	6	R16.S2.03-S1.01-A	44.242917	-72.659021		Moretown	Tributaries to Upper Mid-Winooski	Moderate	Town of Moretown, Central Vermont Regional Planning Commission
38	9	Buffer planting on R16.S2.03-S1.01-A	Plant native trees and shrubs along ~800 feet of the southern bank of the brook and ~200 feet along the northern bank where buffer vegetation is lacking due to lawn.	River - Planting	5	R16.S2.03-S1.01-A	44.242549	-72.659524		Moretown	Tributaries to Upper Mid-Winooski	Moderate	Winooski Natural Resources Conservation District, Friends of the Winooski River, Landowner(s)
39	9	Investigate gully remediation in R16.S2.03-S1.01-B	Investigate remediation of gully coming off the south valley wall.	Floodplain/Stream Restoration - Preliminary Design	6	R16.S2.03-S1.01-B	44.241517	-72.665037	Source of gully is unknown.	Moretown	Tributaries to Upper Mid-Winooski	Low	Central Vermont Regional Planning Commission, Winooski Natural Resources Conservation District, Friends of the Winooski River, Landowner(s)
40	9	Buffer planting on R16.S2.03-S1.01-B	Buffer is lacking for ~500 feet; plant native trees and shrubs to regenerate it.	River - Planting	5	R16.S2.03-S1.01-B	44.241557	-72.665563	Some trees right along bank but not many. Severe erosion along bank.	Moretown	Tributaries to Upper Mid-Winooski	Moderate	Winooski Natural Resources Conservation District, Friends of the Winooski River, Landowner(s)
41	9	Investigate berm removal - R16.S2.03-S1.01-B	Investigate options to remove berm on north bank to improve floodplain access.	Floodplain/Stream Restoration - Preliminary Design	6	R16.S2.03-S1.01-B	44.241663	-72.66613	Berm is short - only ~75 feet long and has large trees growing on it. Removal may not be very feasible/practical.	Moretown	Tributaries to Upper Mid-Winooski	Low	Central Vermont Regional Planning Commission, Winooski Natural Resources Conservation District, Friends of the Winooski River, Landowner(s)
42	9	Buffer planting in pasture on R16.S2.03-S1.01-C	Buffer is lacking for ~250 feet along a horse pasture. Plant native trees and shrubs to regenerate.	River - Planting	5	R16.S2.03-S1.01-B	44.243611	-72.674142	Some trees right along bank; buffer could be expanded to offset impacts from adjacent pasture.	Moretown	Tributaries to Upper Mid-Winooski	Moderate	Winooski Natural Resources Conservation District, Friends of the Winooski River, Landowner(s)
43	9	Livestock exclusion in R16.S2.03-S1.01-C	Investigate alternatives for livestock exclusion at horse ford.	Agricultural Pollution Prevention - Preliminary Design	65	R16.S2.03-S1.01-B	44.243721	-72.674383	Ford is stable and doesn't appear to be a major issue.	Moretown	Tributaries to Upper Mid-Winooski	Low	Natural Resources Conservation Service, US Fish & Wildlife Service, Winooski Natural Resources Conservation District, Friends of the Winooski River, Landowner(s)

No photo for Project #1

Project #2

Project #3

Project #4

Project #5

Project #6

Project #7

Project #8


Project #9


Project #10


Project #11


Project #12


Project #13


Project #14


Project #15


Project #16


Project #17


Project #18


Project #19


Project #20


Project #21


Project #22


Project #23


Project #24


Project #25


Project #26


Project #27


Project #28


Project #29


Project #30


Project #31


Project #32

No photo for project #33


Project #34


Projects #35


Project #36


Project #37


Project #38


Project #39


Project #40


Project #41


Project #42


Project #43