Little River Corridor Plan

Stowe, Waterbury, Morristown, Worcester, Bolton, Underhill and Cambridge, Vermont

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1.0 EXECUTIVE SUMMARY

The River Corridor Planning effort is sponsored by the Lamoille County Planning Commission (LCPC) with funding provided through a grant from the Agency of Natural Resources Clean and Clear Program and the Federal Emergency Management Agency (FEMA). The Vermont Department of Environmental Conservation (DEC) River Management Program provided technical expertise and shared quality control/quality assurance responsibilities with Bear Creek Environmental, LLC (BCE). The River Corridor Plan (RCP) followed the Vermont Agency of Natural Resources River Corridor Planning Guide. Information for the RCP came from the DEC, the Vermont Center for Geographic Information (VCGI), and field data collected by BCE and LCPC.

The primary objective of the RCP is to use stream geomorphic assessment data to identify and prioritize river corridor protection and restoration projects within the Little River watershed primarily in the Town of Stowe. 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 Vermont Stream Geomorphic Assessment Protocol includes three phases:

1. Phase 1- Remote sensing and cursory field assessment;
2. Phase 2 – Rapid habitat and rapid geomorphic assessment 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.

A Phase 1 Stream Geomorphic Assessment following Agency of Natural Resources Protocols was completed for the Little River watershed by Lamoille County Planning Commission (LCPC) and BCE during 2006, and a Phase 2 Stream Geomorphic Assessment following Agency of Natural Resources Protocols was completed for Little River by BCE during summer 2007. During Phase 1, the Little River watershed was divided into 138 reaches, encompassing roughly 83 miles of river channel. Four of these reaches that were impounded by lakes, ponds or wetlands were excluded from the Phase 1 assessment. Reaches on the West Branch of the Little River were also excluded because this subwatershed was previously assessed using Phase 1 and 2 protocols. A corridor plan for the West Branch using the stream geomorphic assessment information was prepared in 2007 by LCPC (Lamoille County Planning Commission 2007).

Phase 2 field work was conducted within the Little River watershed in 2007 on the Little River main stem, Gold Brook, Miller Brook and Moss Glen Brook; approximately 21 miles of river were assessed. Bridge and culvert data collected by J Schwartz during August and September 2006 were used in conjunction with data collected by BCE during the Phase 2 assessment to identify structures that have the potential to fail because of channel adjustments, are having a geomorphic impact on the stream, or are impeding aquatic organism passage.

The major problems in the Little River watershed include lack of riparian buffers, channel straightening, and poor floodplain access. The lack of forested riparian buffers has led to extensive bank erosion and invasive species growing on the river banks and within the river corridor. Japanese knotweed is an invasive plant species that is prevalent in both the riparian buffer and the corridor within the Little River mainstem and Miller Brook. The Little River mainstem from the Waterbury Reservoir to above Stowe village has been extensively channelized and straightened with a combination of rock riprap, hard bank armoring, and berms. These activities have contributed to poor floodplain access. At total of 24 berms were mapped as part of the stream geomorphic assessment. Eleven of these berms are on Gold Brook. Gravel extraction and dredging of the lower reaches of the major tributaries and the Little River mainstem has also contributed to channel straightening, removal of woody vegetation and loss of large woody debris. Alteration of stream channels has caused major channel degradation resulting in sediment build up, channel widening and planform adjustment. The channel modification activities, floodplain encroachment, gravel mining, channel straightening, and excessive build up of sediment have all resulted in reduced aquatic habitat.

As the river works toward a more stable equilibrium, the community of Stowe has the opportunity to provide long-term protection to the river corridor and encourage the reestablishment of floodplain vegetation and healthy instream habitat. At the reach and site level, potential restoration and protection projects that would be compatible with geomorphic adjustments and managing the stream toward equilibrium conditions were identified. A list of 51 potential restoration and conservation projects was developed during project identification. Types of projects include: river corridor protection through corridor easements and conservation efforts, replacing undersized structures causing localized channel instability, improving riparian buffers, and alternative analyses for removing dams and streamside berms.

2.0 LOCAL PLANNING PROGRAM OVERVIEW

2.1 River Corridor Planning Team

The river corridor planning team for the Little River watershed is comprised of the Lamoille County Planning Commission, the Agency of Natural Resources, Bear Creek Environmental, LLC, local municipalities and landowners. This planning effort is sponsored by the Lamoille County Planning Commission. Funding for the project is provided through a grant from the Clean and Clear Program and FEMA. Gretchen Alexander from the Vermont River Management Section of the Vermont Agency of Natural Resources (VANR) provided technical guidance for this project.

2.2 Goals and Objectives of the Project

The primary objective of the River Corridor Management Plan is to use the Phase 1 and 2 Stream Geomorphic Assessment data to identify and prioritize river corridor protection and restoration projects within the Little River watershed. The State of Vermont's River Management Program has set out several goals and objectives that are supportive of the local initiative in the Little River watershed. 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, 2007b). 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. Additionally, 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.

3.0 BACKGROUND WATERSHED INFORMATION

3.1 Geographic Setting

3.1.1 Watershed Description

The Little River has a watershed size of 112 square miles (Figure 3.1). The Phase 2 study focused on stream reaches on the main stem of the Little River and the lowest stream reaches on Miller Brook, Gold Brook and Moss Glen Brook. The combined length of the stream reaches assessed is approximately 21 miles. The Little River begins as Sterling Brook in the headwaters of Mount Mansfield near the boundary of Stowe and Morristown. The Little River heads southeast and then south through the Town of Stowe, where it joins with the West Branch of the Little River see Figure 3.2. Downstream of downtown Stowe, the Little River crosses the town boundary of Stowe and Waterbury and enters Washington County. The Little River flows into the Winooski River at approximately 390 feet above sea level, which then drains westerly into Lake Champlain.

3.1.2 Political Jurisdictions

The Little River watershed flows through seven towns (Cambridge, Underhill, Morristown, Stowe, Waterbury, Worcester and Bolton). Phase 1 and Phase 2 reaches for the Little River are located in Lamoille, Washington and Chittenden Counties (Figure 3.2). The Little River watershed falls under the jurisdiction of the LCPC, the Central Vermont Regional Planning Commission (CVRPC) and the Chittenden County Regional Planning Commission. LCPC is the regional planning commission for the 10 towns in Lamoille County. This project focused on only those reaches within Lamoille County and under the jurisdiction of the LCPC.

3.1.3 Land Use

Geographic Information System (GIS) data from 1992 was obtained from the Vermont Center for Geographic Information (VCGI) to analyze landuse within the Little River watershed. The majority of the Little River is forested (Figure 3.3). The landuse breakdown for the watershed is 77 percent forest, 9 percent agriculture, 4 percent developed and urban land, 8 percent water and 1 percent wetland. The most concentrated areas of development in the watershed are along the Mountain Road and at the intersection of the Mountain Road and Route 100 in Stowe as well as in downtown Waterbury Center. Agricultural lands are prevalent within the Little River and the West Branch corridor in Stowe. Lands marked as agricultural lands in the upper part of the West Branch are actually ski trails and not agricultural land.

The Mount Mansfield Natural Area, Mount Mansfield State Forest and CC Putnam State Forest are public lands within the Little River watershed. A description of each of these areas is included under Section 3.5 (Ecological Setting).

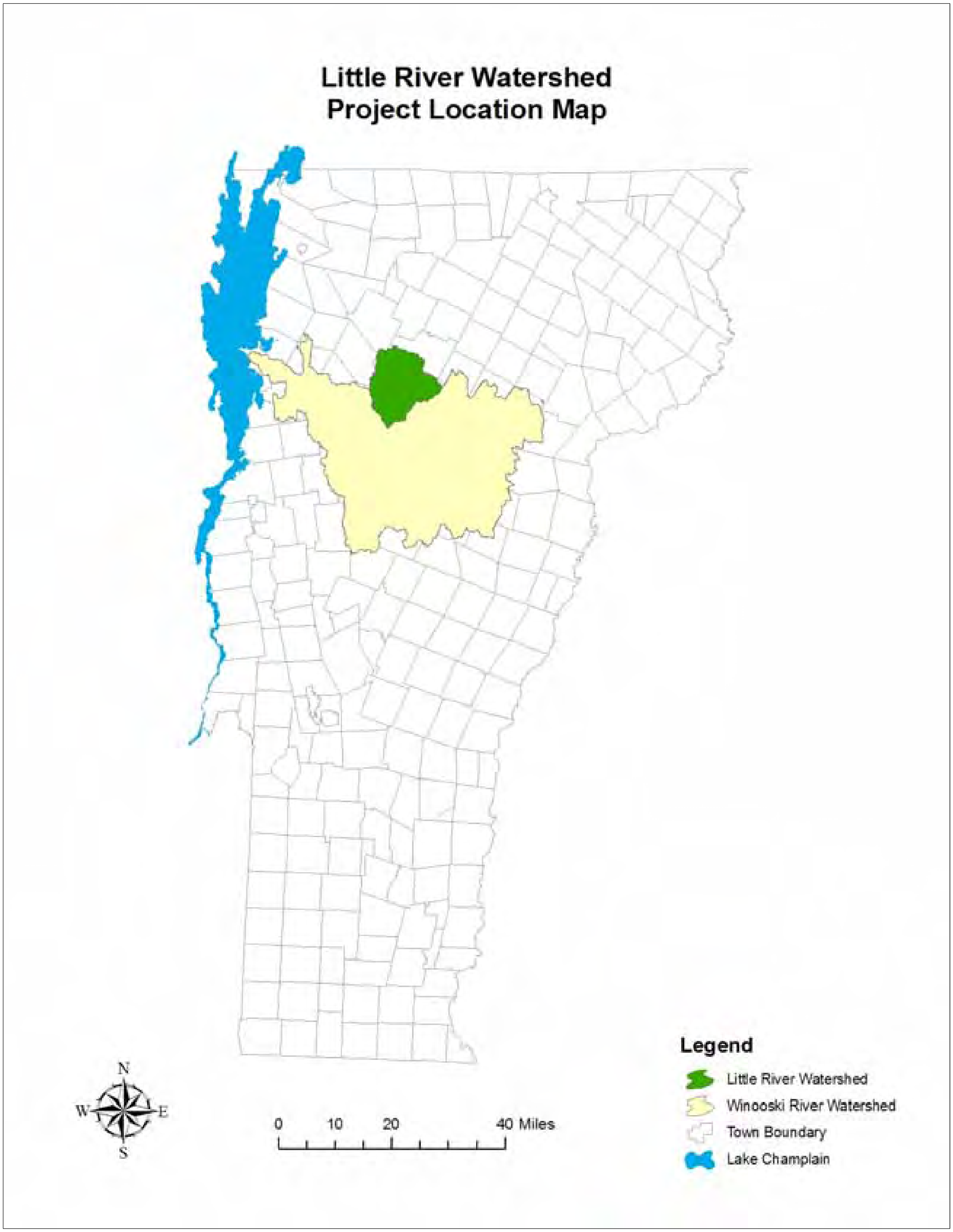

Figure 3.1. Project Location Map for the Little River Watershed

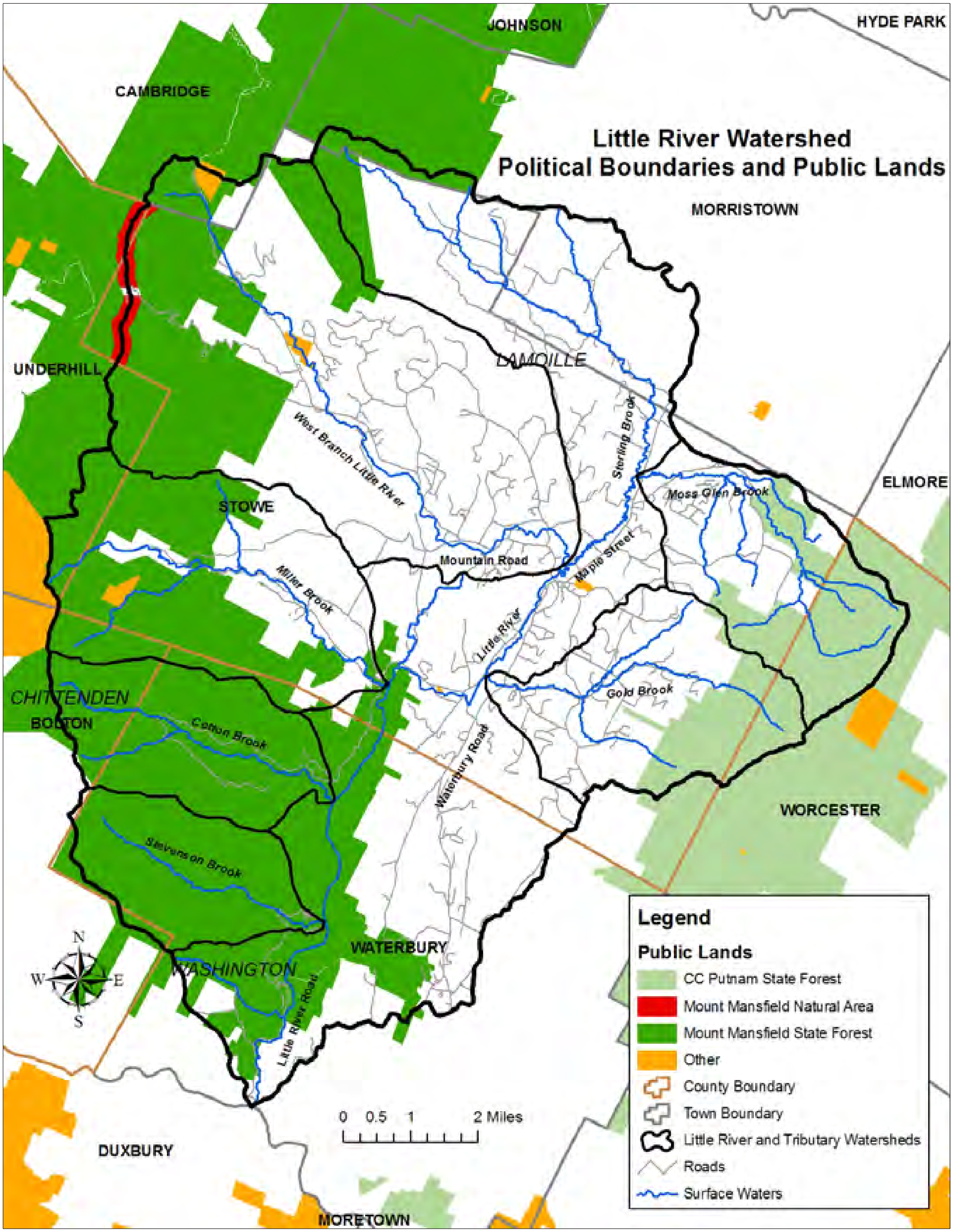

Figure 3.2. Little River Political Boundaries and Public Lands

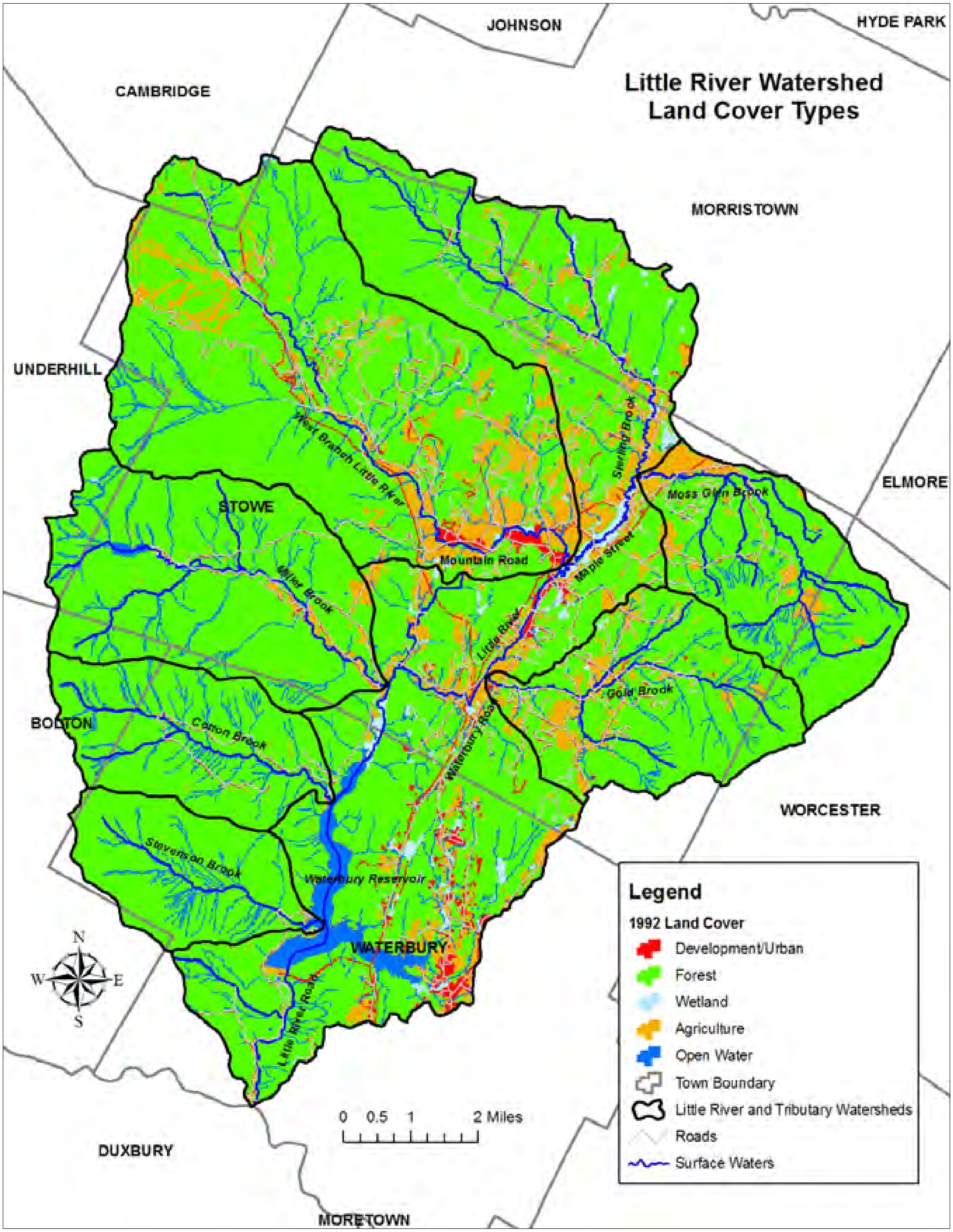

Figure 3.3. Land Cover and Land Use Map for the Little River Watershed

3.2 Geologic Setting

The Little River watershed is located within the Green Mountain Geo-physiographic Province. The Green Mountains were uplifted during the Taconic orogeny about 455 million years ago (Doolan, 1996). The bedrock underlying the Little River watershed primarily consists of the Hazens Notch Formation and the Stowe Formation. The Hazens Notch Formation is comprised of interbedded carbonaceous and noncarbonaceous schist. The Stowe Formation is located in the eastern part of the watershed. The Stowe Formation is comprised of quartz and chlorite phyllite and schist with abundant segregations of granular white quartz. Within the Stowe Formation at this location are also greenstone and amphibolite rocks. The western part of the watershed contains a thin section of the Underhill Formation. The Underhill Formation is comprised of silvery, gray-green schist with many segregations of granular white quartz. Nestled in between the Stowe Formation and the Hazens Notch Formation is the Ottauquechee Formation. The Ottauquechee Formation is comprised of black carbonaceous phyllite or schist with interbeds of quartzite (Doll, 1961).

The Green Mountains and adjacent valleys have been covered with ice during historic glacial periods. The last large ice sheet, the Laurentide Ice Sheet, covered all of New England and advanced up the Winooski River Valley. As the climate warmed, the glacier slowly retreated and glacial lakes were dammed in the Winooski River valley. Following the retreat of the ice sheet, the Winooski River and its tributaries began eroding the glacial and lake sediments that were left behind (Wright, 2003).

Natural Resource Conservation Service (NRCS) soils information for the Little River watershed was acquired from GeologicSoils_So (Vermont Center for Geographic Information, 2008). The dominant surficial geology of the Little River watershed consists of glacial till as shown in Figure 3.4. Outwash (ice-contact deposits), alluvial and lacustrine deposits are subdominant within the watershed. Alluvial deposits, outwash, and lacustrine are dominant within the Little River and the West Branch corridors. The watershed is primarily comprised of highly erodible and potentially highly erodible soils (Figure 3.5). Except for along the Waterbury Reservoir, there are concentrated areas of non-highly erodible soils within the Little River corridor in Waterbury and Stowe and within the West Branch corridor downstream of the Ranch Brook confluence. Non-highly erodible soils are also located within the corridors of Moss Glen Brook and the downstream reaches of Miller Brook.

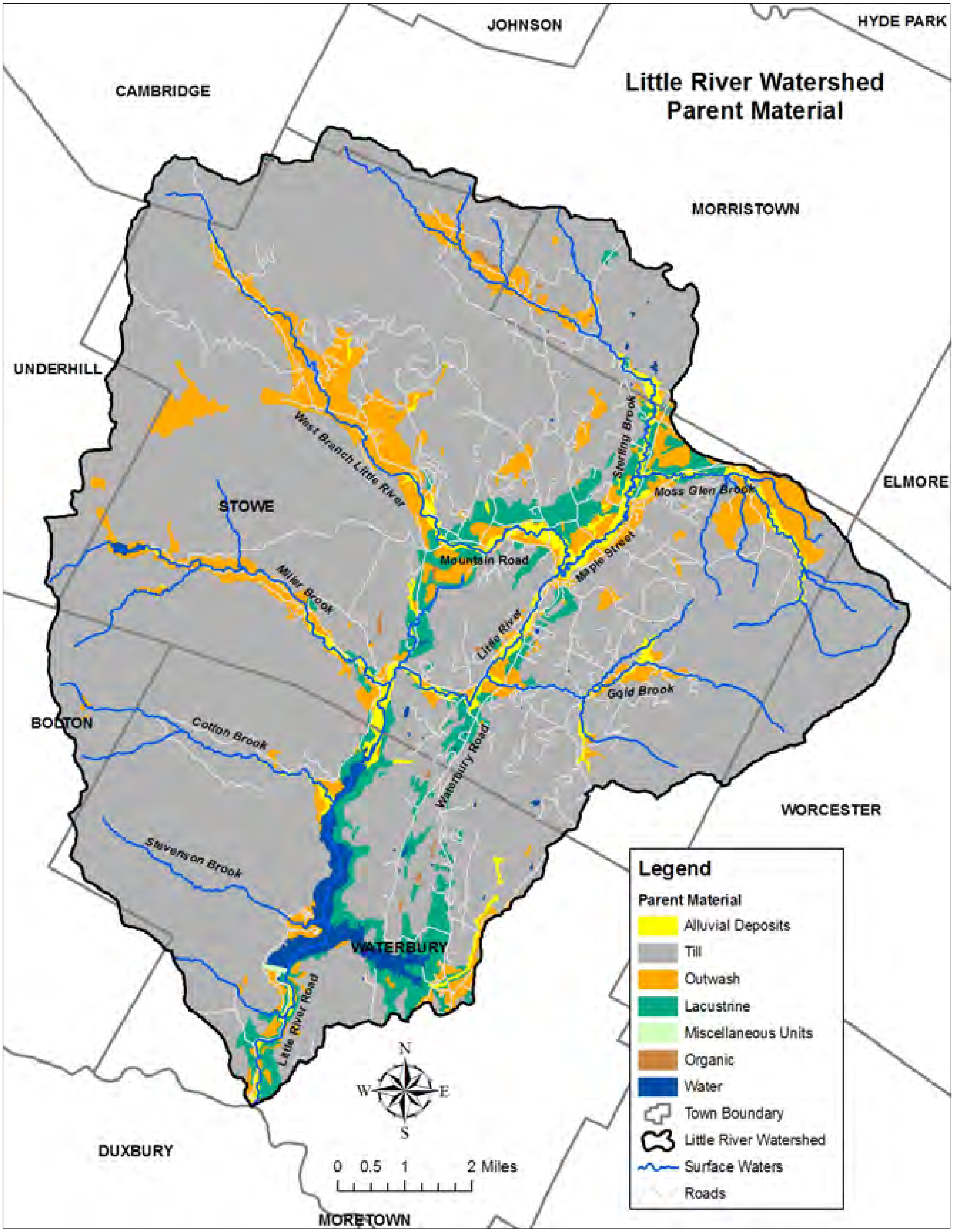

Figure 3.4 Little River Watershed Soil Parent Material

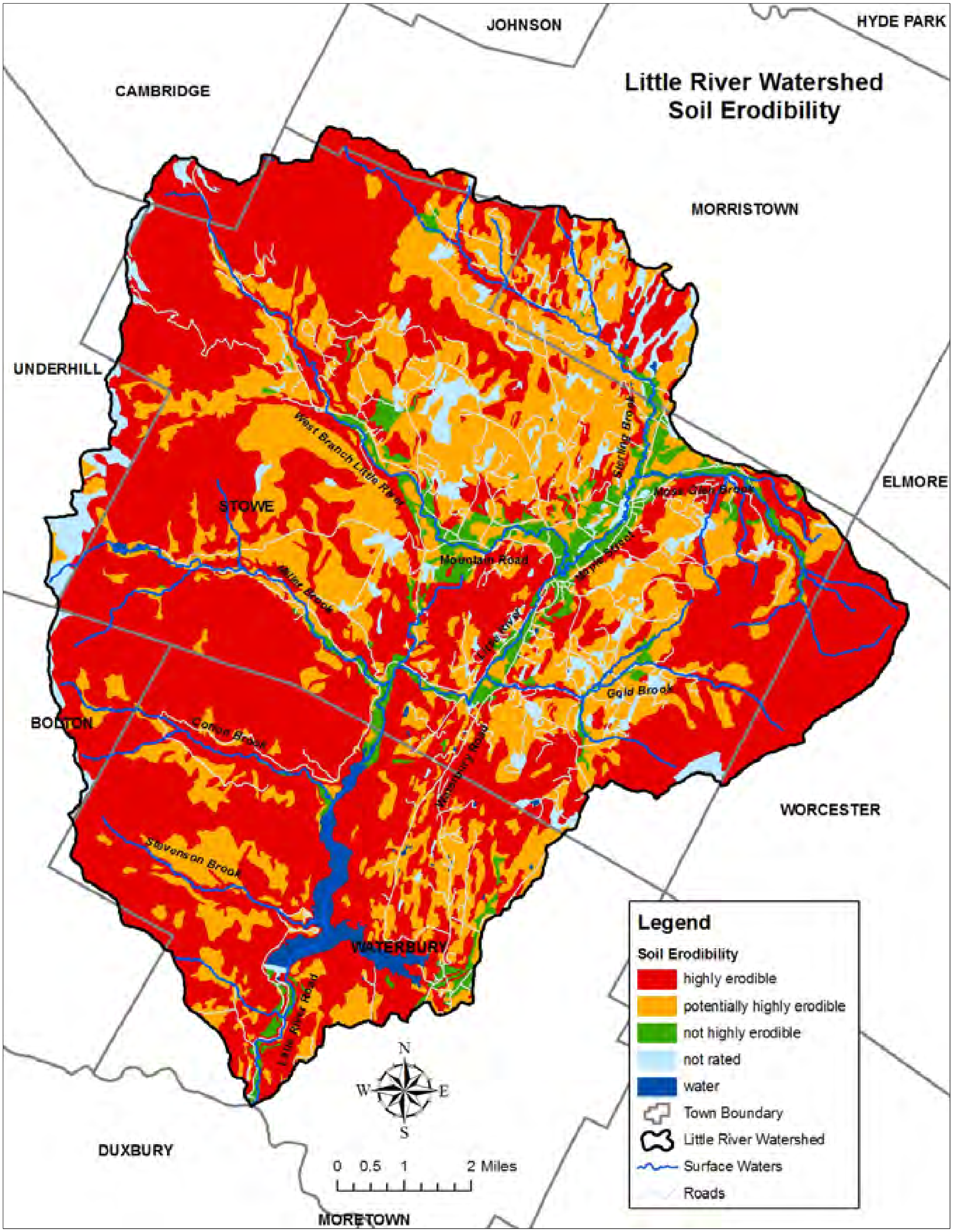

Figure 3.5 Little River Soil Erodibility

3.3 Geomorphic Setting

A Phase 1 Stream Geomorphic Assessment was conducted on 138 reaches of the main stem of the Little River, three major tributaries (Miller Brook, Gold Brook and Moss Glen Brook) and twelve unnamed tributaries. The West Branch of the Little River was excluded from the study since it was assessed under another project. The Cotton Brook and Stevenson Brook watersheds as well as two unnamed tributary watersheds were excluded from the study since they were located in Waterbury and outside the scope of this project (Figure 3.6). The Phase 2 study focused on 16 stream reaches on the main stem of the Little River within the Towns of Stowe and Morristown, five reaches on Miller Brook, seven reaches on Gold Brook and three reaches on Moss Glen Brook. The combined length of the stream reaches assessed during the Phase 2 study is approximately 21 miles (Figure 3.7). 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. Each point represents the downstream end of the reach.

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, and/or watershed. Stream and valley characteristics including valley confinement, and slope were determined from digital USGS topographic maps. The reference reach characteristics were refined during the windshield survey and Phase 2 Assessment. Reference reach typing was based on both the Rosgen (1996) and the Montgomery and Buffington (1997) classification systems. Table 1 shows the typical characteristics used to determine reference stream types (Vermont Agency of Natural Resources, 2007b). Reference stream types for the assessed reaches are listed in Table 2. With the exception of three reaches, which are “B” channels by reference, all the reference stream types on the main stem of the Little River assessed for Phase 2 are “C” channels. Reference “C” channels have unconfined valleys with moderate to gentle valley slopes and moderate to high width to depth ratios and sinuosity. The rest of the reaches on the main stem are either “B” or “A” channels by reference. “B” channels have moderate to steep slopes and have narrower valleys than “C” channels. “A” channels have very steep slopes and are confined or narrowly confined. All Phase 2 assessed reaches on Miller Brook and Moss Glen Brook have a reference stream type of “C”. Gold Brook contains three reaches with a “B” stream type and the remaining reaches are “C” channels by reference (Figure 3.8).

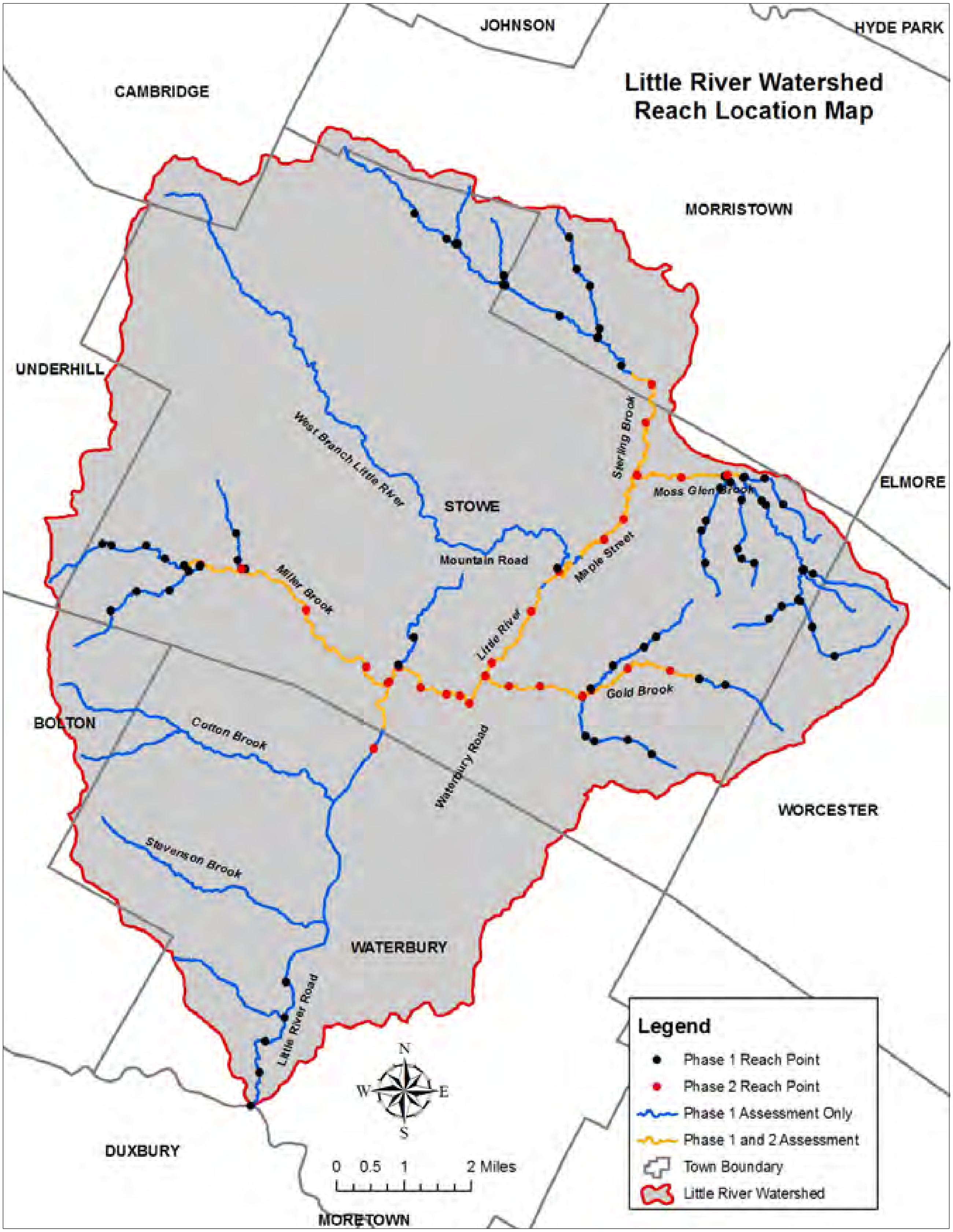

Figure 3.6 Little River Watershed Reach Location Map

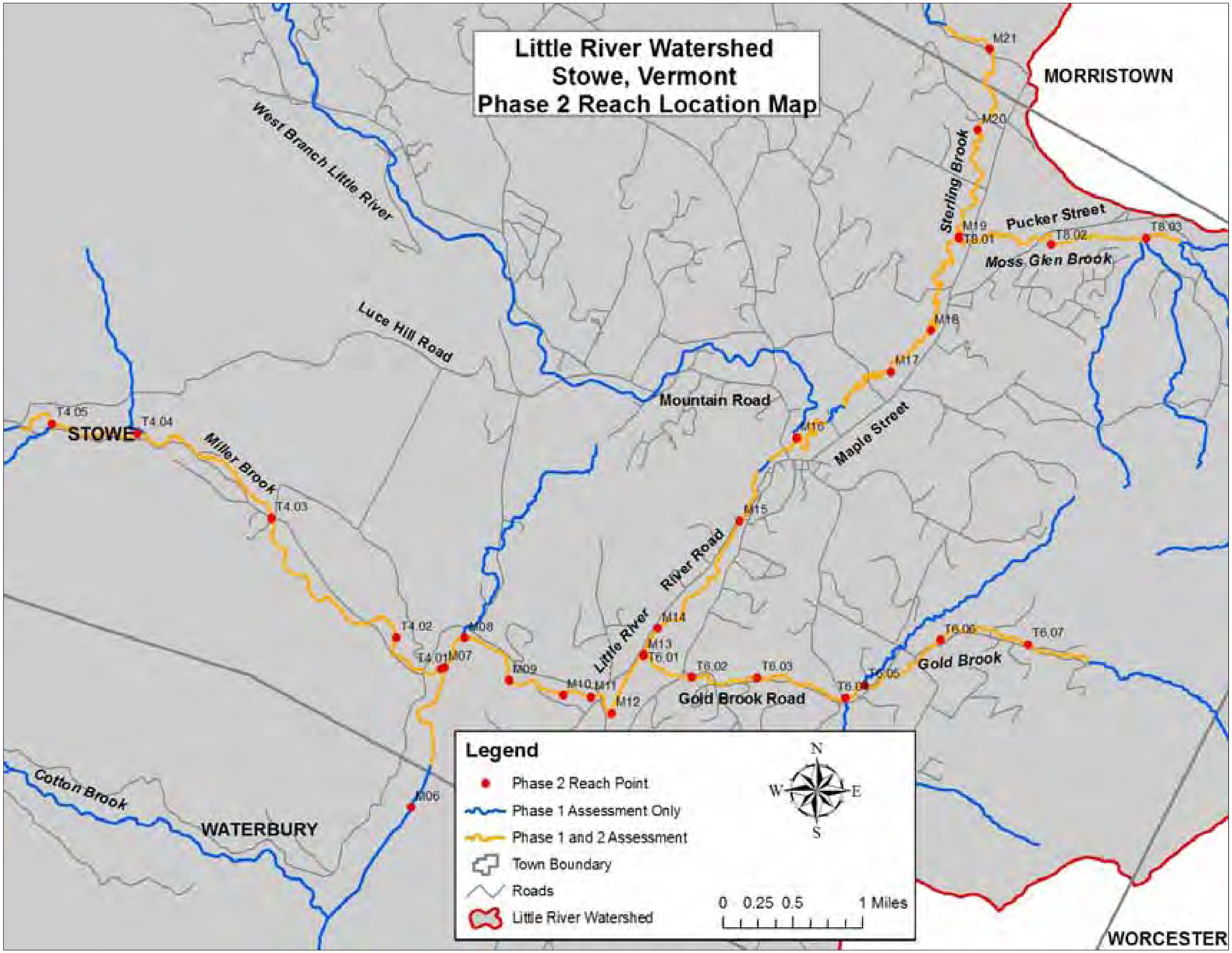

Figure 3.7 Reach location map for Phase 2 Stream Geomorphic Assessments

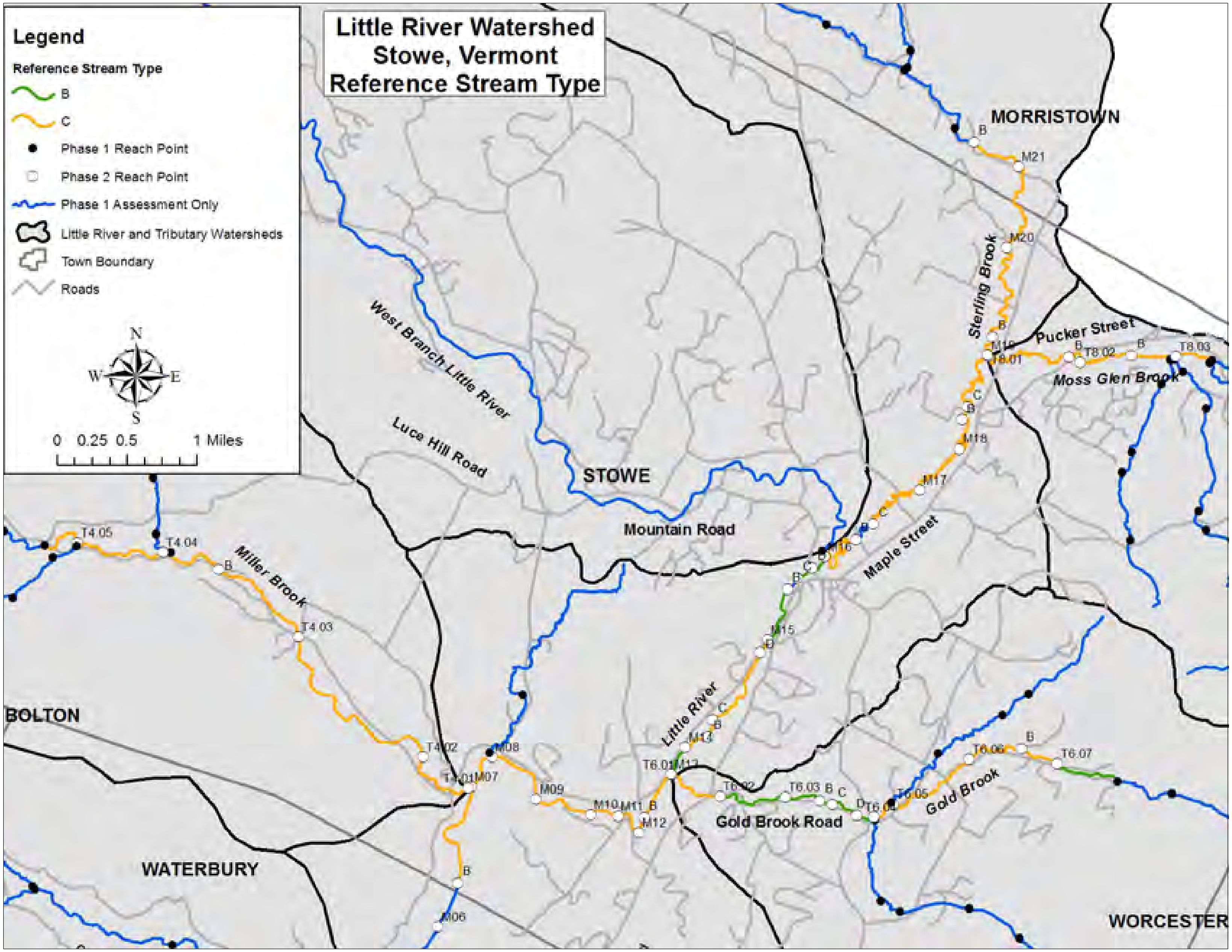

Figure 3.8 Reference Stream Type for Phase 2 Geomorphic Assessments

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

Table 2: Geomorphic Setting of Assessed Reaches				
Reach ID	**Reference Stream Type**	**Confinement**	**Valley Slope**	**Bedform**
M06	C	Very Broad	0.27	Riffle-Pool
M07	C	Broad	0.06	Riffle-Pool
M08	C	Narrow	0.04	Riffle-Pool
M09	C	Broad	0.36	Riffle-Pool
M10	C	Broad	0.78	Riffle-Pool
M11	C	Broad	0.10	Riffle-Pool
M12	C	Very Broad	0.19	Riffle-Pool
M13	B	Semi-Confined	0.43	Riffle-Pool
M14	C	Broad	0.29	Riffle-Pool
M15	B	Semi-Confined	0.98	Riffle-Pool
M16	C	Very Broad	0.32	Riffle-Pool
M17	C	Very Broad	0.21	Riffle-Pool
M18	C	Very Broad	0.16	Riffle-Pool
M19	C	Very Broad	0.54	Riffle-Pool
M20	C	Very Broad	1.02	Riffle-Pool
M21	C	Broad	1.88	Riffle-Pool

Table 2: Geomorphic Setting of Assessed Reaches

Reach ID	Reference Stream Type	Confinement	Valley Slope	Bedform
T4.01	C	Very Broad	0.56	Riffle-Pool
T4.02	C	Very Broad	1.44	Riffle-Pool
T4.03	C	Very Broad	2.82	Riffle-Pool
T4.04	C	Broad	2.81	Riffle-Pool
T4.05	C	Broad	1.79	Riffle-Pool
T6.01	C	Very Broad	2.12	Riffle-Pool
T6.02	B	Semi-Confined	3.71	Step-Pool
T6.03	B	Broad	2.56	Riffle-Pool
T6.04	C	Very Broad	2.37	Riffle-Pool
T6.05	C	Very Broad	2.32	Riffle-Pool
T6.06	C	Very Broad	4.49	Riffle-Pool
T6.07	B	Narrow	7.05	Step-Pool
T8.01	C	Very Broad	0.82	Riffle-Pool
T8.02	C	Very Broad	0.65	Riffle-Pool
T8.03	C	Very Broad	1.14	Riffle-Pool

3.4 Hydrology

In order to better understand the flood history of the Little River, long term data from the U.S. Department of the Interior, U.S. Geological Survey (USGS) gauge on the Little River in Waterbury, VT were obtained (USGS 2009). Seventy-three years of record (1936-2008) are available for the Little River gauge.

The long term record for the Little River shows that 1936 had the highest flow on record and exceeded the 50 year discharge. The 25 year discharge was exceeded in 1995. The long term record on the Little River gauge shows major flood events also occurred in the years 1937, 1938, 1990, 1996 and 2008. The graph below (Figure 3.9) provides a flood frequency analysis for the Little River gauge. The flow at this gauge is affected by regulation or diversion at the dam for Waterbury Reservoir.

Of all the natural hazards experienced in Vermont, flooding is the most frequent, damaging, and costly. Over the last 50 years, flood recovery has cost Vermonters an average of 14 Million dollars a year. During the period of 1995-1998 alone, flood losses in Vermont totaled nearly $57 Million. 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 erosion caused by rivers and streams, and can range from gradual bank erosion to catastrophic changes in river channel location and dimension during flood events (Vermont Agency of Natural Resources 2006).

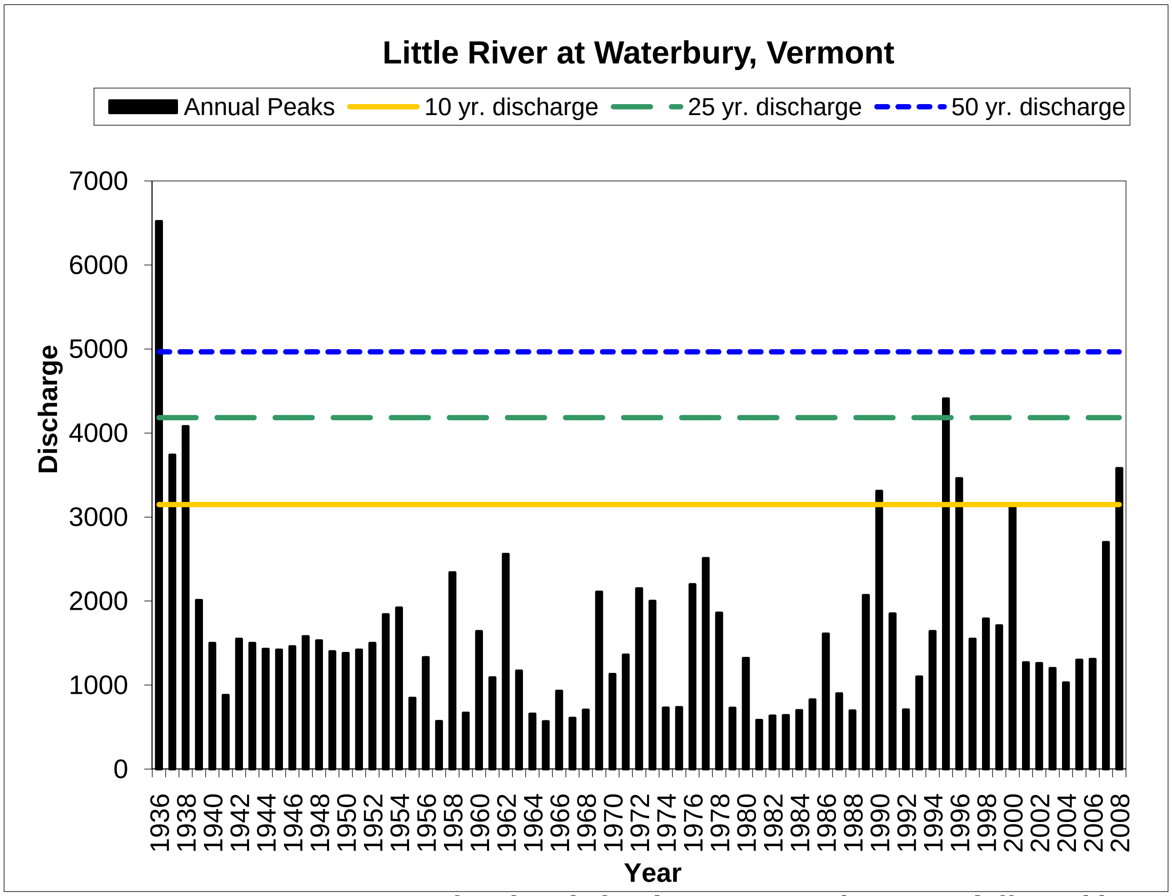

Figure 3.9. Flood frequency analysis for the Little River at Waterbury, VT (affected by regulation and diversion).

Closer study of our rivers and streams reveals that Vermont's erosion hazard problems are largely due to pervasive, human-caused alteration during the past 150 to 200 years of our waterways and landscapes they drain. By end of the nineteenth century, forests had been cleared from many watersheds, resulting in major changes in watershed hydrology and sediment production. Towns and villages, the centers of commerce, grew on the banks of rivers. Benefits of power generation and transportation initially outweighed flood risks. In addition, many watersheds were changed by development, agriculture, log drives, roads and railways. The legacy of this landscape manipulation is rivers, such as the Little River, which are unstable and prone to fluvial erosion (Vermont Agency of Natural Resources 2006). The Waterbury Dam was created in response to local floods that occurred in the early 1900's. Torrential rains on November 3 and 4, 1927 resulted in high water in the Little River, which drove residents to their roofs. A second flood in 1934 was the impetus for creating the Waterbury Dam. The dam was created between 1935 and 1938 by the Civilian Conservation Corps in cooperation with the Corps of Engineers. (Wildernet.com, Accessed March 11, 2010 (a)).

Flooding events are usually correlated with extreme weather patterns. The majority of the twentieth century's largest floods have occurred during the summer months of June through August and are associated with intense cloudbursts, which stay in the mountains producing high rainfall amounts. The remainder is divided quite evenly between fall floods (September through November) which are often associated with hurricanes. Winter/spring floods (January through April) are associated with rain on snow events or snowmelt. Summer and fall floods are associated with greater flood damage than winter snowmelt floods. A flood in July 2004 in Stowe dropped as much as 4 inches of rain in one hour causing almost $500,000 in flood damage according to the Federal Emergency Management Agency (Barg, 2004).

3.5 Ecological Setting

The Little River watershed lies exclusively within the Northern Green Mountains biophysical region (Figure 3.8). This region is characterized by Thompson and Sorenson (2005) as having high elevations and cool summers. The Green Mountains have a strong influence on the weather resulting in an abundance of precipitation in the form of both rain and snow. Precipitation within the West Branch watershed averages 53 inches annually (USGS, Scott Olson, pers. comm., 2004). On the top of Mount Mansfield annual precipitation averages over 78 inches. Precipitation increases with elevation, at about an inch per 1000 feet of elevation (Wemple, 2002). Mount Mansfield receives more precipitation than most areas in the State. An orographic effect often occurs on Mount Mansfield where convection off of sunny slopes leads to thunderstorms. Since the prevailing winds off of the Green Mountains are from the west, air rising through convection is shifted downwind and therefore increases precipitation onto the opposite (east slope). The direction from which the air comes affects the outcomes of storms. Air which arrives from the south is usually moisture laden and causes extreme rainfall events, while storms that come from the north or northwest typically have dry air.

Northern hardwood forest is the dominant community in the Northern Green Mountains biophysical region. The Northern Green Mountains provide important habitat for both aquatic and terrestrial animals. According to Thompson and Sorenson (2005), the Green Mountains offer extensive habitat for black bear, white-tailed deer, bob cat, fisher, beaver and red squirrel. Birds such as blackpoll warbles, Swainson's thrush and the rare Bicknell's thrush nest in the high elevation forests.

The Vermont Significant Wetland Inventory GIS layer ("WaterWetland_VSWI") provides important information about the distribution of wetland habitat within the Little River watershed. Wetland habitat is located adjacent to the Little River south of the confluence with Miller Brook as well as along the Little River in the vicinity of Maple Road. Wetland habitat is also common in the southeast portion of the watershed.

Deer wintering areas identified by the Vermont Agency of Natural Resources in the shapefile "EcologicHabitat_DEERWN" last updated May 1, 2006 are common within the watershed as shown in Figure 3.10. Rare, Threatened and Endangered Species & Significant Communities from the shapefile "EcologicOther_RTENATCOM" prepared by the Vermont Fish and Wildlife Department, Nongame and Natural Heritage Program (last updated in 2009) are mapped in Figure 3.10 to better understand the ecological setting of the Little River watershed. The western portion of the Little River watershed has been identified by the Nongame and Natural Heritage Program as a significant terrestrial community. Much of this area identified as significant terrestrial community is part of the Mount Mansfield State Forest (see Figure 3.2). The Mount Mansfield State Forest is 37, 242 acres and is the largest forest in Vermont (Wildernet.com, Accessed March 11, 2010 (a)). The Mount Mansfield Natural Area is also part of the area identified as a significant terrestrial community. Located along the western ridge of the Little River watershed, this important natural area offers a subalpine spruce-fir forest. The CC Putman State Forest, located on the eastern side of the Little River watershed, is a 13,355 acre state forest within the Woodbury Mountain Range. Camping, fishing, hiking and hunting are all recreation opportunities within this State forest. (Wildernet.com, Accessed March 11, 2010 (b)).

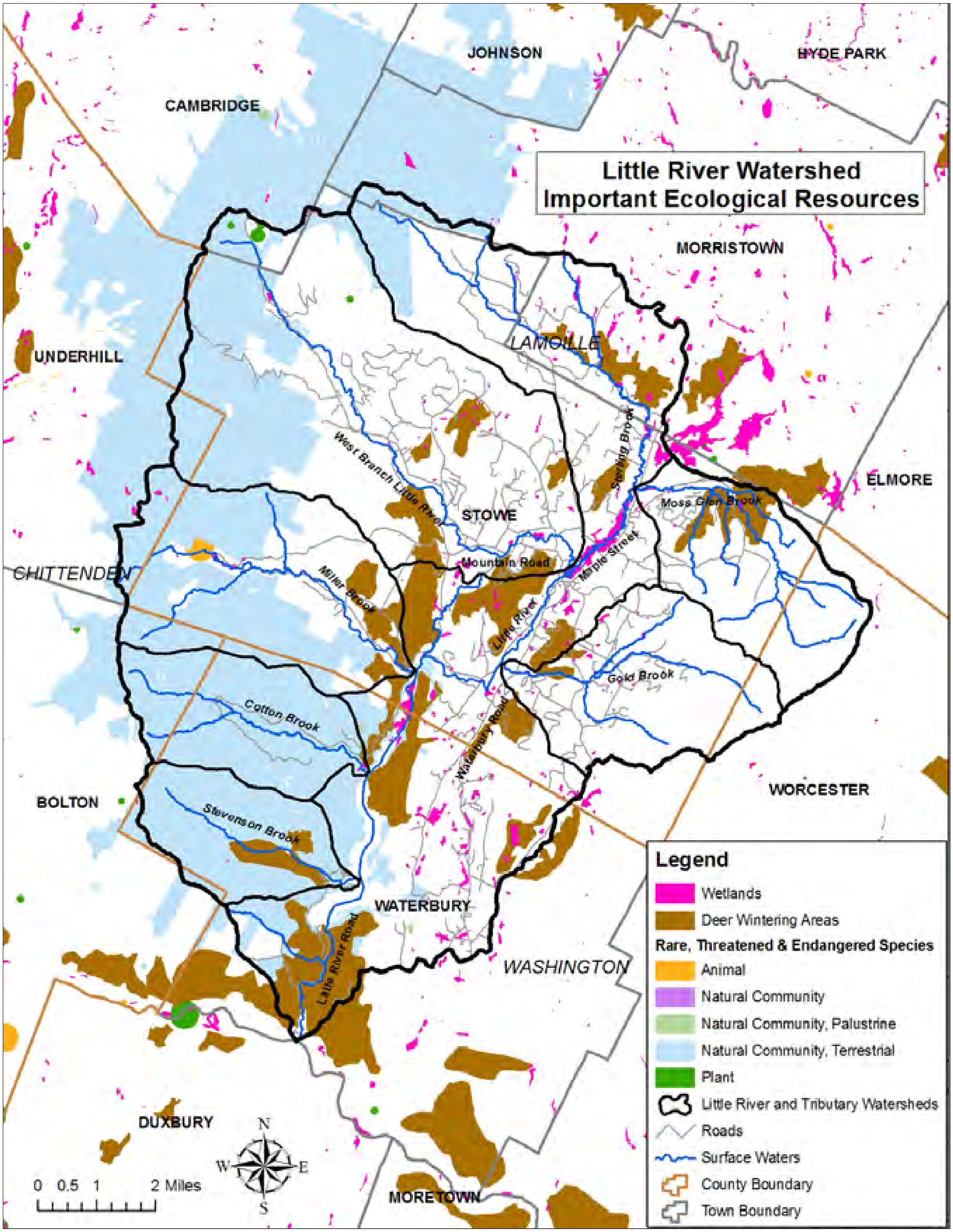

Figure 3.10. Important ecological resources within the Little River watershed

4.0 METHODS

4.1 Phase 1 Methodology

A Stream Geomorphic Assessment process is divided into three phases, based on VANR protocols. 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" (Vermont Agency of Natural Resources, 2006). The Phase 1 assessment provides an overview of the general physical nature of the watershed. A Phase 1 Assessment of the Little River watershed was completed by the Lamoille County Planning Commission in 2006.

4.2 Phase 2 Methodology

The Phase 2 assessment of the Little River watershed followed procedures specified in the Vermont Stream Geomorphic Assessment Handbook Phase 2 (Vermont Agency of Natural Resources, 2007b). All assessment data were recorded on the Agency of Natural Resources Phase 2 data sheets, and were entered in to the VANR Stream Geomorphic Assessment data management system (DMS). The Phase 1 database was updated using the field data from the Phase 2 assessment in 2007.

The parameters and protocols used for undertaking the Phase 2 assessment are outlined in the Phase 2 Handbook (Vermont Agency of Natural Resources, 2007b). The entire length of each Phase 2 reach was walked to determine segment breaks. Bank erosion, grade control structures, bank revetments, debris jams, depositional features, stormwater inputs, flood chutes, valley walls and other important features were mapped within all segments. BCE used the Stream Geomorphic Assessment Tool (SGAT) version 4.56 to index features that were mapped during the Phase 2 assessment. SGAT is an ArcView extension.

4.3 Bridge and Culvert

Bridge and culvert inventory and assessments were conducted by J Schwartz in August and September 2006 to determine if stream crossings were contributing to localized streambank erosion, sedimentation, and reduced fish passage. Thirty of these structures are located within the Little River Phase 2 study area. The Agency of Natural Resources Bridge and Culvert protocols (Vermont Agency of Natural Resources, 2007b) were followed. The Vermont Culvert Geomorphic Screening Tool (Milone and MacBroom, Inc., 2008a) and the Vermont Culvert Aquatic Organism Passage Screening Tool (Milone and MacBroom, Inc, 2008b) were used to identify culverts within the Little River watershed that are highest priority for replacement/retrofit due to geomorphic incompatibility and/or for being potential barriers to movement and migration of aquatic organisms. The Vermont Culvert Geomorphic Screening Tool was modified for bridges. This modification for bridges includes a score for percent bankfull width, approach angle, erosion and armoring, and sediment continuity. Slope is not included as it is with the evaluation of culverts.

4.4 River Corridor Plan

The Vermont Agency of Natural Resources River Corridor Planning Guide (2007a) and Draft 9 of Chapter 5 of the plan dated October 2, 2007 were followed to generate a series of stressor maps, which are included in Section 6.0. The stressor maps were created using indexed data from the Phase 1 and Phase 2 Stream Geomorphic Assessments along with existing data available from VCGI, including e911 roads, e911 buildings and e911 driveways. The stressor maps were then used to identify potential project locations that have few constraints to channel adjustment.

4.5 Quality Control/Quality Assurance Procedures

To assure a high level of confidence in the Phase 1 and 2 SGA data, strict quality assurance/quality control (QA/QC) procedures were followed by BCE. These procedures involved a thorough in-house review of all data as well as automated and manual QC checks with the DEC River Management Program.

In 2008, BCE completed its own in-house QA review after all the Phase 2 data were entered into the DMS and the Phase 1 data were updated. The Phase 1 DMS and ArcView shapefiles were updated by Colleen Sullivan and Mary Nealon based on the Phase 2 field assessment work during the Phase 2 QA/QC process. The DMS and the ArcView shapefiles for the Little River Phase 2 study were submitted to Gretchen Alexander of the VANR for a Quality Assurance review in spring 2008. Some minor revisions were made by BCE to the DMS following this review and the VANR QA review was completed in October 2008.

5.0 RESULTS

5.1 Phase 2 Results

Rapid Geomorphic Assessment

During the Phase 2 assessment, sixteen reaches on the mainstem of the Little River were broken into 30 segments based on detailed field observations. The reference and existing stream type for each assessed segment is included in Figure 5.1. Detailed segment summary data are provided in Appendix A.

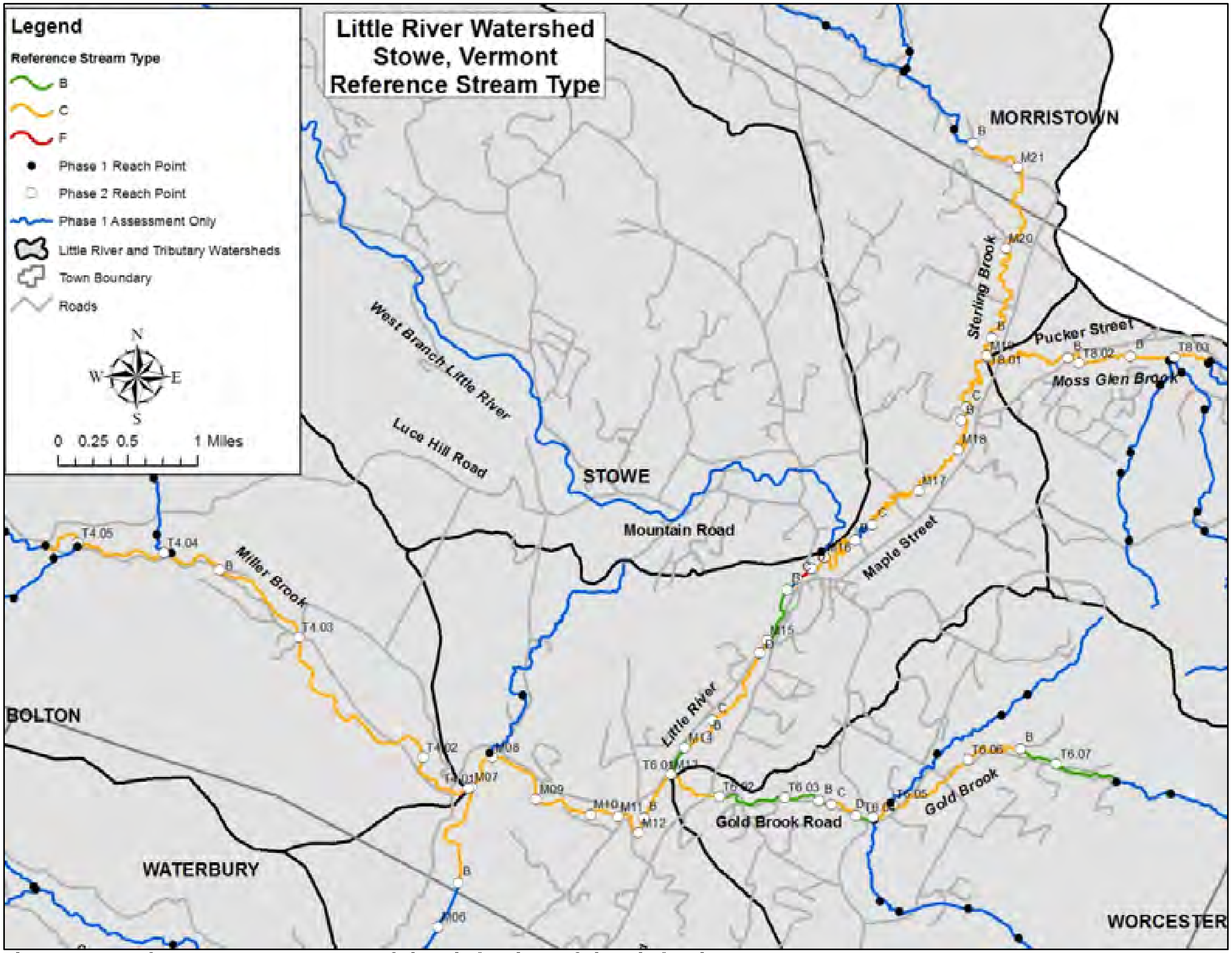

Figure 5.1. Reference stream types of the Little River of the Little River

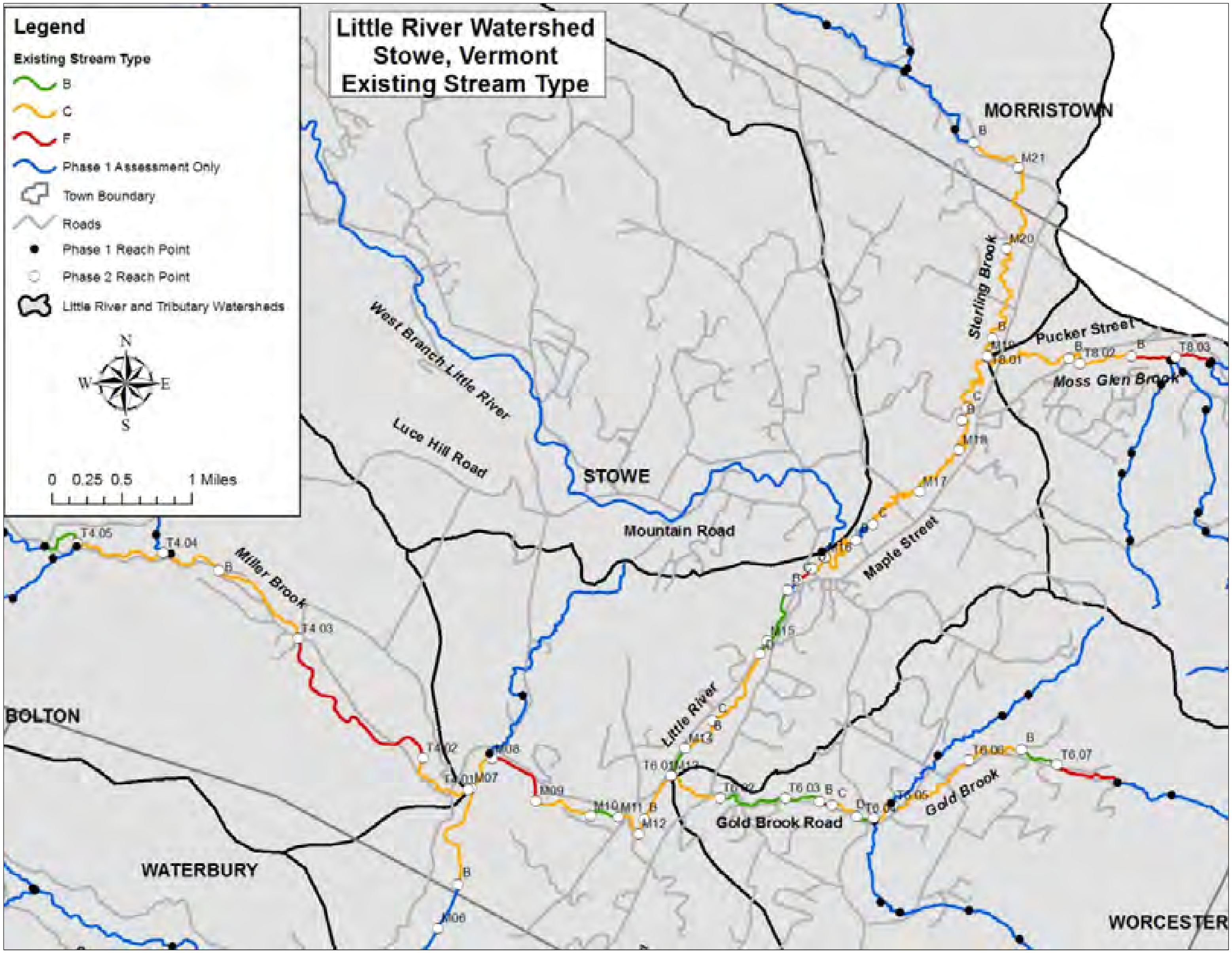

Figure 5.2 Existing stream types of the Little River watershed

All but one of the Phase 2 reaches/segments on the main stem of the Little River within the Phase 2 study area are Rosgen (1996) "C" channels by reference; M13 and M15 are semi-confined "B" channels. All assessed reaches on Miller Brook and Moss Glen Brook are "C" channels by reference. On Gold Brook, all except three reaches are "C" channels by reference. The other three reaches are "B" channels by reference. There are many reaches/segments where the existing stream type differs from the reference stream type or a stream type departure has taken place. 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. Stream type departures from a reference "C" channel with slight entrenchment to a "Bc" channel with moderate entrenchment have occurred in reaches/segments M10, M14-D and T4.05. A slightly more extreme stream type departure occurred in two reaches/segments on Gold Brook (T6.03-B and T6.07) where moderately entrenched "B" channels have became very entrenched "F" channels. An even more extreme stream type departure from a reference "C" channel with slight entrenchment to an entrenched "F" channel has occurred in reaches/segments M08, T4.02, T8.02-B and T8.03. These stream type departures represent a significant change in floodplain access and stability. Watersheds which 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 (Vermont Agency of Natural Resources, 2007a).

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, and 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 within the Little River watershed include:

- Forest clearing
- Channelization and bank armoring
- Removal of woody riparian vegetation
- Floodplain encroachments
- Poor road maintenance and installation of infrastructure
- Loss of wetlands

These anthropogenic practices have altered the balance between water and sediment discharges within the Little River watershed. Channel morphologic responses to these practices contribute to channel adjustment that may further create unstable channels. All three adjustment processes, aggradation, widening and planform migration as a result of historic degradation within the channel, were common in the Little River watershed. 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 occurs when stream flows are contained in a channel as a result of degradation or floodplain encroachment or when sediments overwhelm the stream channel and the erosive energy is concentrated into both banks.

The existing geomorphic condition is depicted in Figure 5.3. Geomorphic condition is determined based on the degree (if any) of channel degradation, aggradation, widening and planform adjustment. Except for four reaches/segments, the assessed segments and reaches in the Little River watershed were found to be in "fair" geomorphic condition. The other four assessed reaches were in "good" geomorphic condition. Four segments did not receive a full phase 2 assessment. Segment M06-A was not assessed because it was influenced by backwater from the Waterbury Reservoir. Segment M16-B was not assessed due to influence from beaver dams. Two segments (M15-B and M21-B) were not assessed because they are located in bedrock gorges.

The reach condition ratings of the Little River indicate that most of the reaches are actively, or have historically, undergone a process of minor, major or even extreme geomorphic adjustment. Many of the reaches studied in the Little River watershed are undergoing a channel evolution process in response to large scale changes in its sediment, slope, and/or discharge associated with the human influences on the watershed. Table 3 below summarizes the channel evolution of each study reach and the primary adjustment processes that are occurring.

Both the "D" stage and "F" stage channel evolution model (Vermont Agency of Natural Resources, 2007b) are helpful for explaining the channel adjustment processes underway in the Little River watershed. The "F" stage channel evolution model 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 5.4 include:

- A pre-disturbance period
- Incision – channel degradation
- Aggradation and channel widening
- The gradual formation of a stable channel with access to its floodplain at a lower elevation

The "D-stage" channel evolution model applies to reaches where there may have been some minor historic incision; however, the more dominant active adjustment process is aggradation, which in turn leads to channel widening and planform adjustment. The D-stage adjustment process typically occurs in unconfined, low to moderate gradient valleys where the stream is not entrenched and has access to its floodplain or flood prone area at the 1-2 year flood stage.

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 streambanks. 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.

Channel equilibrium can be assessed by looking at the regimes of sediment transport within the watershed. The analysis of sediment regimes at the watershed scale is useful for summarizing the stressors affecting the equilibrium condition of river channels. Sediment regime mapping provides a context for understanding the sediment transport and channel evolution processes which govern changes in geometry and planform for river channels in a state of disequilibrium.

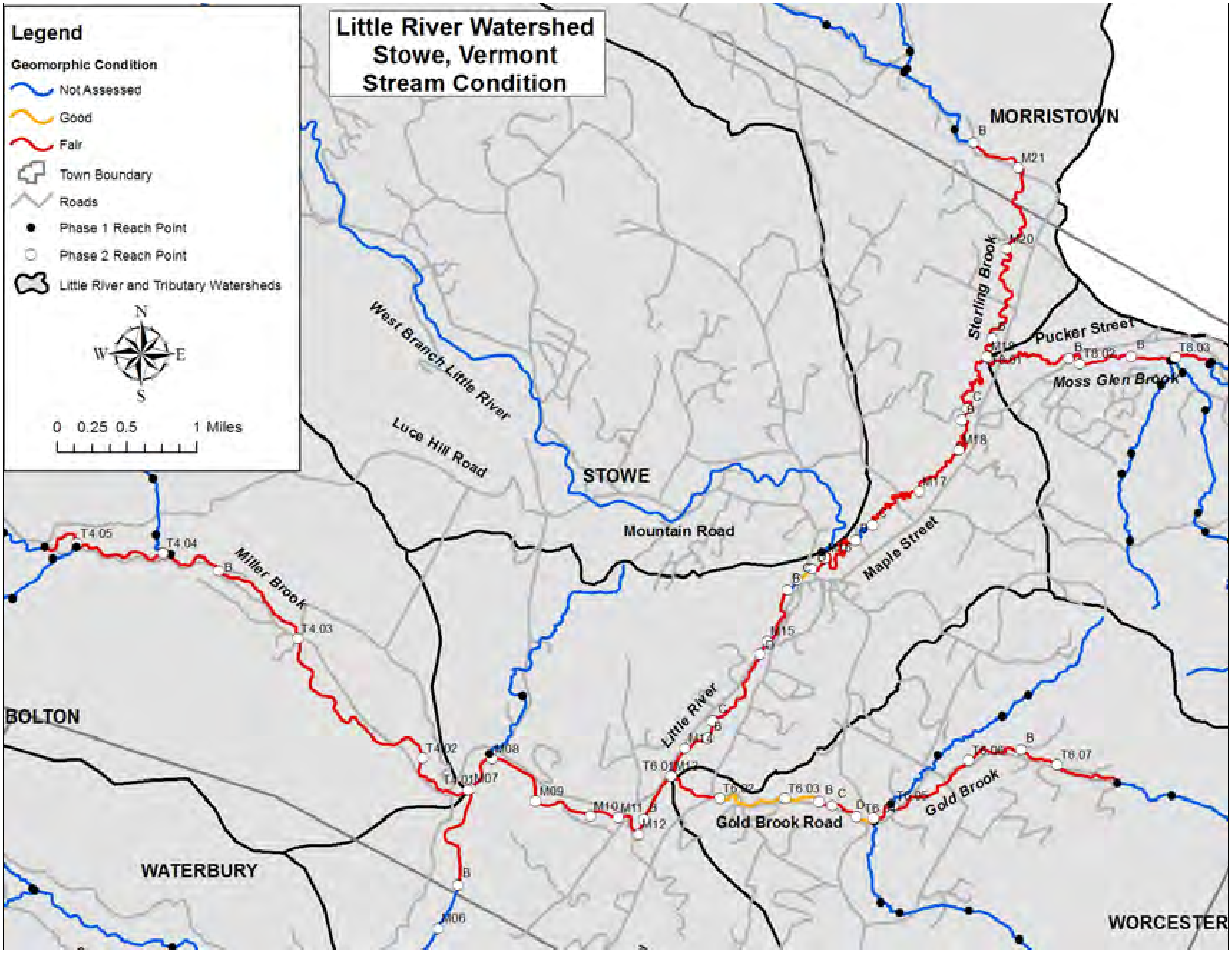

Figure 5.3. Phase 2 Geomorphic Condition of the Little River Watershed

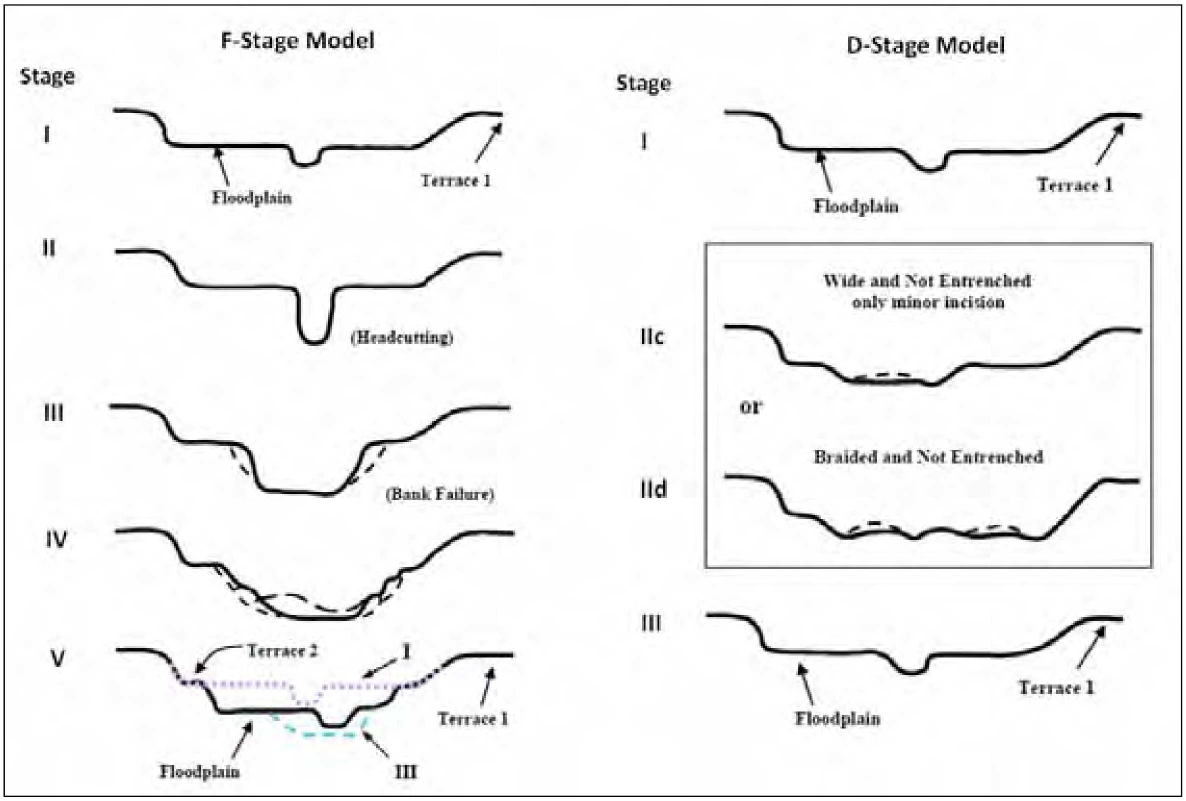

Figure 5.4 Typical channel evolution model for F-Stage and D-Stage (Vermont Agency of Natural Resources, 2007b)

	Table 3. Stream Type and Channel Evolution Stage						
Segment Number	**Entrenchment Ratio**	**Width to Depth Ratio**	**Reference Stream Type**	**Incision Ratio**	**Existing Stream Type**	**Channel Evolution Stage**	**Active Adjustment Process**
M06-B	2.95	41.4	C4	1.95	C4	F-III	**Aggradation** **Widening** Planform
M07	2.39	38.7	C4	2.08	C4	F-IV	**Aggradation** **Widening** **Planform**
M08	1.23	24.6	C4	1.95	F4	F-III	Aggradation **Widening** Planform
M09	3.27	23.1	C4	1.98	C4	F-III	**Aggradation** **Widening** Planform
M10	1.38	31.0	C4	2.26	B4c	F-III	**Aggradation** Widening Planform
M11	4.83	38.4	C4	1.28	C4	F-III	**Aggradation** **Widening** Planform

	Table 3. Stream Type and Channel Evolution Stage						
Segment Number	**Entrenchment Ratio**	**Width to Depth Ratio**	**Reference Stream Type**	**Incision Ratio**	**Existing Stream Type**	**Channel Evolution Stage**	**Active Adjustment Process**
M12-A	10.91	18.2	C4	1.47	C4	F-III	Aggradation Widening Planform
M12-B	12.82	27.5	C4	1.30	C4	F-III	Aggradation Widening Planform
M13	2.07	23.2	B5c	1.51	B5c	F-III	Aggradation **Widening Planform**
M14-A	2.18	21.8	C4	1.62	C4	F-III	Aggradation Widening **Planform**
M14-B	8.77	16.8	C4	1.47	C4	F-II	Aggradation Widening Planform
M14-C	5.73	23.3	C4	1.71	C4	F-III	**Aggradation Widening Planform**
M14-D	1.45	22.2	C4	1.87	B4c	F-II	Aggradation Widening Planform
M15-A	1.45	22.2	B4c	1.87	B4c	F-II	Aggradation Widening Planform
M15-C	1.21	18.2	F3	1.00	F3	F-I	Widening
M15-D	2.84	25.1	C4	1.45	C4	F-III	Aggradation Widening Planform
M16-A	15.50	22.5	C5	1.31	C5	F-III	**Aggradation Widening Planform**
M16-C	23.81	11.5	C4	1.53	C4	F-III	**Aggradation** Widening **Planform**
M17	9.70	21.5	C4	1.63	C4	F-III	**Aggradation** Widening **Planform**
M18-A	17.48	12.0	C4	1.49	C4	F-III	**Aggradation** Widening **Planform**
M18-B	17.05	11.4	C4	1.74	C4	F-III	Aggradation Widening Planform
M18-C	17.48	12.0	C4	1.49	C4	F-III	**Aggradation Widening Planform**

	Table 3. Stream Type and Channel Evolution Stage						
Segment Number	Entrenchment Ratio	Width to Depth Ratio	Reference Stream Type	Incision Ratio	Existing Stream Type	Channel Evolution Stage	Active Adjustment Process
M19-A	37.54	22.7	C4	1.69	C4	F-III	**Aggradation** **Widening** **Planform**
M19-B	9.90	20.2	C4	1.47	C4	F-III	**Aggradation** Widening **Planform**
M20	19.06	10.9	C4	1.00	C4	D-IIc	**Aggradation** Widening **Planform**
M21-A	8.56	20.8	C4	1.00	C4	D-IIc	**Aggradation** Widening **Planform**
T4.01	2.30	50.4	C4	1.52	C4	F-III	**Aggradation** **Widening** **Planform**
T4.02	1.20	30.5	C4	2.00	F4	F-III	**Aggradation** Widening **Planform**
T4.03-A	2.29	21.9	C3b	1.37	C3b	F-III	**Aggradation** Widening **Planform**
T4.03-B	2.57	19.5	C3b	1.90	C3b	F-III	**Aggradation** Widening Planform
T4.04	2.88	23.5	C4b	1.86	C4b	F-III	Aggradation Widening **Planform**
T4.05	1.33	25.7	C3	2.00	B3c	F-II	Aggradation Widening Planform
T6.01	5.86	23.9	C4	1.77	C4	F-III	Aggradation Widening **Planform**
T6.02	1.33	24.7	B4	1.00	B4	D-IIb	**Aggradation** Widening Planform
T6.03-A	1.89	23.3	B3	1.00	B3	F-I	Widening
T6.03-B	1.28	21.0	B3	2.85	F4b	F-II	Aggradation Widening Planform
T6.03-C	2.78	29.2	C4b	1.20	C4b	D-IId	**Aggradation** Widening Planform
T6.03-D	1.50	22.3	B3	1.00	B4	F-I	Widening
T6.04	5.82	13.8	C4b	1.43	C4b	F-III	Aggradation Widening Planform

	Table 3. Stream Type and Channel Evolution Stage						
Segment Number	**Entrenchment Ratio**	**Width to Depth Ratio**	**Reference Stream Type**	**Incision Ratio**	**Existing Stream Type**	**Channel Evolution Stage**	**Active Adjustment Process**
T6.05	5.69	13.6	C4b	1.39	C4b	F-III	Aggradation Widening Planform
T6.06-A	3.42	15.8	C3b	1.36	C3b	F-III	Aggradation Widening **Planform**
T6.06-B	1.60	21.8	B4a	1.76	B4a	F-II	Aggradation Widening **Planform**
T6.07	1.15	24.5	B3a	2.41	F4a	F-II	Aggradation Widening Planform
T8.01-A	2.01	13.8	C4	1.62	C4	F-III	**Aggradation** Widening Planform
T8.01-B	11.43	39.5	C4	1.86	C4	F-IV	Aggradation **Widening** Planform
T8.02-A	9.06	43.1	C4	1.00	C4	F-IV	**Aggradation Widening Planform**
T8.02-B	1.15	21.6	C4	2.79	F4	F-III	Aggradation Widening Planform
T8.03	1.26	26.2	C4	2.37	F4	F-III	**Aggradation Widening** Planform
	Bold Red lettering – denotes extreme adjustment process **Bold Black lettering** – denotes major adjustment process Black lettering (no bold) – denotes minor adjustment process Pink denotes high width to depth ratio Red denotes severe incision ratio Blue denotes moderate incision ratio Green denotes a stream type departure						

In terms of the VANR channel evolution model, the Little River is predominately at stage III of the "F-stage" channel evolution model. In many reaches the channel has undergone historic degradation as evidenced by abandoned terraces. Many of the cross sections on study reaches were found to be incised, with eight segments having severe incision ratios. The incision ratios ranged from 1.0 to 2.85. Along many of the reaches and near the mouths of the tributaries, the system is actively adjusting to this lower bed elevation by moving laterally and widening in order to create a new floodplain at a lower elevation. This widening and planform adjustment is leading to another adjustment process, aggradation. Aggradation in the Little River study area seems to be a combination of endogenous sediment that is created as the stream widens and erodes its banks to reestablish a new floodplain as well as from exogenous sources such as gravel roads and land clearing. Unvegetated mid-channel bars, point bars, side bars, avulsions, flood chutes and impending neck cutoffs confirm the Little River is undergoing extensive lateral migration. Three segments in the study area (M15-C, T6.03-A and T6.03-D) were found to be in stage I of the "F-stage" channel evolution model, wherein the channel has not yet incised and no major adjustment processes are occurring.

Four segments within the Little River study area (M20, M21-A, T6.02 and T6.03-C) fall into the "D-stage" evolution model, where the more dominant active adjustment process is aggradation. This build up of sediment leads to channel widening and planform adjustment. Some of these segments have undergone some minor historic incision; however, the more dominant active adjustment process is aggradation. Segment T6.03-C on Gold Brook (D-IId stage) is undergoing extreme aggradation. This has led to major channel widening and planform adjustment. Reach T6.02 on Gold Brook falls into the D-IIb stage. Channel incision has not occurred in reach T6.02 due to the resistance of bedrock grade controls on the streambed. The dominant process in this reach is aggradation. The stream is a very entrenched "B" stream type.

Two segments on the main stem (M20 and M21-A) fall into the D-IIc stage. The stream channel has not incised in segment M20 and has only slightly incised in M21-A. In the D-IIc stage, a steeper gradient may have been imposed through activities such as channelization, but due to the resistance of the bed material, or a downstream grade control, the stream has not incised or lost access to its floodplain (remaining a "C" Stream Type). There is some minor widening and major planform adjustment as the channel migrates laterally through bank erosion caused by the increased stream power. The balance between stream power and boundary materials is re-established when the slope flattens after a process of channel lengthening and increased sinuosity. The stream bed in these channels may be a combination of poorly defined riffle-pool features and plane bed features.

Nine reaches have experienced stream type departures. Four reaches with "C" reference stream types (M08, T4.02, T8.02-B and T8.03) have become "F" channels. Two segments (T6.03-B and T6.07) have evolved from "B" channels to "F" channels. Three segments (M10, M14-D and T4.05), which were once "C" channels, are now "B" channels. Most of these stream type departures are likely due to channel alteration and/or encroachment within the river corridor thereby resulting in extreme incision. Reach T4.05 is located just downstream of an on-stream dam and has been starved of sediment, resulting in extreme incision and a change in stream type.

HABITAT EVALUATION

Table 4 below shows a comparison of the habitat condition based on the Rapid Habitat Assessment (RHA) and the geomorphic condition based on the Rapid Geomorphic Assessment (RGA). For thirty of the 48 assessed segments, both the RHA and the RGA resulted in a "fair" rating. Three segments (T6.02, T6.03-A and T6.03-D) had a rating of "good" for both the RHA and the RGA. One segment (M15-C) had a rating of "fair" for habitat but "good" for geomorphic condition, and fourteen segments had a rating of "good" for habitat but "fair" for geomorphic condition. Many of the reaches that had been straightened or had floodplain alterations lacked a strong riffle-pool bedform and the diversity of habitat features that this brings. Numerous reaches had major intrusion into their river corridor from roads, and many reaches had inadequate riparian buffers due to historic and /or recent land clearing. Overall, the RHA score was similar to the RGA score, implying that the ecological health of the Little River is closely related to the geomorphic condition of the stream.

Table 4. Comparison of RHA and RGA for Phase 2 Reaches

Segment Number	Score RHA	Score RGA	Rating RHA	Rating RGA
M06-A	Impounded - Not Assessed			
M06-B	0.60	0.44	Fair	Fair
M07	0.60	0.39	Fair	Fair
M08	0.54	0.45	Fair	Fair
M09	0.56	0.45	Fair	Fair
M10	0.58	0.49	Fair	Fair
M11	0.58	0.54	Fair	Fair
M12-A	0.46	0.55	Fair	Fair
M12-B	0.59	0.58	Fair	Fair
M13	0.50	0.49	Fair	Fair
M14-A	0.60	0.54	Fair	Fair
M14-B	0.48	0.59	Fair	Fair
M14-C	0.55	0.40	Fair	Fair
M14-D	0.55	0.53	Fair	Fair
M15-A	0.53	0.53	Fair	Fair
M15-B	Bedrock Gorge – Not Assessed			
M15-C	0.64	0.76	Fair	Good
M15-D	0.61	0.61	Fair	Fair
M16-A	0.59	0.48	Fair	Fair
M16-B	Beaver Dam Influence – Not Assessed			
M16-C	0.57	0.46	Fair	Fair
M17	0.66	0.44	Good	Fair
M18-A	0.58	0.46	Fair	Fair
M18-B	0.57	0.58	Fair	Fair
M18-C	0.60	0.46	Fair	Fair
M19-A	0.57	0.44	Fair	Fair
M19-B	0.63	0.44	Fair	Fair
M20	0.68	0.60	Good	Fair
M21-A	0.68	0.58	Good	Fair
M21-B	Bedrock Gorge – Not Assessed			
T4.01	0.65	0.41	Good	Fair
T4.02	0.62	0.38	Fair	Fair

Table 4. Comparison of RHA and RGA for Phase 2 Reaches

Segment Number	Score RHA	Score RGA	Rating RHA	Rating RGA
T4.03-A	0.60	0.50	Fair	Fair
T4.03-B	0.71	0.53	Good	Fair
T4.04	0.68	0.49	Good	Fair
T4.05	0.81	0.56	Good	Fair
T6.01	0.47	0.51	Fair	Fair
T6.02	0.76	0.69	Good	Good
T6.03-A	0.70	0.80	Good	Good
T6.03-B	0.64	0.53	Fair	Fair
T6.03-C	0.66	0.53	Good	Fair
T6.03-D	0.73	0.78	Good	Good
T6.04	0.68	0.61	Good	Fair
T6.05	0.71	0.59	Good	Fair
T6.06-A	0.65	0.54	Good	Fair
T6.06-B	0.71	0.55	Good	Fair
T6.07	0.66	0.54	Good	Fair
T8.01-A	0.55	0.56	Fair	Fair
T8.01-B	0.45	0.44	Fair	Fair
T8.02-A	0.58	0.51	Fair	Fair
T8.02-B	0.55	0.53	Fair	Fair
T8.03	0.68	0.41	Good	Fair

5.2 Bridge and Culvert Assessment

A total of 30 structures (26 bridges and 4 culverts) are located within the Phase 2 Little River study area (Figure 5.5). Twenty-five of these stream crossings are on public roads. A bridge and culvert assessment using the VANR protocol was conducted of 19 of these structures by J Schwartz during August and September 2006. Bear Creek Environmental, LLC used the VANR bridge and culvert protocol to assess the Waterbury Road crossing during summer 2007. The geomorphic compatibility and AOP screening tools, photographs and Phase 2 constriction notes were used to prioritize structures for replacement/retrofit. A list of resources for towns regarding funding, planning and design for replacement and retrofit of stream crossings is available on the Vermont River Management and the Vermont Department of Fish and Wildlife's web sites:
http://www.vtwaterquality.org/rivers/htm/rv_EducationalResources.htm
http://www.vtfishandwildlife.com/library.cfm?libbase_=Reports_and_Documents).

Table 5 summarizes the data collected for the twenty-four structures that cross public roads within the Phase 2 study reach. The final column of Table 5 includes a prioritization of structures for replacement or retrofit based on three criteria: structure width in relation to bankfull channel width, aquatic organism passage (AOP) and geomorphic compatibility, and notes from the Phase 2 study. One of four priorities for replacement was assigned (NR- not recommended for replacement at this time, low, moderate or high).

Six structures are not recommended for replacement at this time. These structures are all bridges that have structure spans that are at least 100 percent of the bankfull channel width. No significant sediment transport issues were noted at the structures, which were assigned NR. Seven structures were assigned a low priority for replacement/retrofit. The low priority structures are bridges with only minor sediment transport issues. Ten structures were identified as moderate priority for replacement/retrofit. The bridges in the moderate priority category fall within the partially compatible or mostly incompatible category using the geomorphic screening tool. Two culvert crossings on Gold Brook (Bryan Road and North Hollow Road) were placed in the moderate priority category because the structures are undersized and do not have sediment throughout the structure, resulting in reduced aquatic organism passage. Two stream crossings (Upper Hollow Road and Stagecoach Road) were assigned a high priority for replacement. The culvert on Gold Brook that crosses Upper Hollow Road is freefall and has no AOP except for adult salmonids. The twin culverts on Moss Glen Brook at the Stagecoach Road crossing were found to be mostly incompatible using the geomorphic screening tool and have reduced AOP. A summary of the moderate and high priority structures is provided in Appendix B.

Table 5 Little River Watershed Evaluation using VANR Geomorphic Compatibility and AOP Screening Tools								
Stream Name	**Reach/ Segment Number**	**Road Name**	**Structure Type**	**Percent Bankfull Channel Width[1]**	**Aquatic Organism Passage (AOP)**	**Geomorphic Compatibility**	**Phase 2 Constriction Notes**	**Priority for Replacement or Retrofit**
Little River Mainstem	M11	Moscow Road	Bridge	89%[2]	NA	Partially Compatible	Scour above, scour below, Alignment	Moderate
	M15-A	River Road	Bridge	85%[2]	NA	Mostly Compatible	Deposition above (mid-channel bar > ½ bankfull)	Low
	M15-D	Mountain Road	Bridge	120%[2]	NA	Mostly Compatible	Deposition above and scour below	Low
	M16-B	Cemetery Road	Bridge	100%[2]	NA	Fully Compatible	None	NR[5]
	M16-C	West Hill Road	Bridge	113%[2]	NA	No assessment data available	Deposition above, deposition below, scour above, alignment	Low
	M18-B	Little River Farm Road	Bridge	65%[4]	NA	Partially Compatible	Scour above; rip-rap within structure acting as channel constriction	Moderate
Sterling Brook	M19-B	Tansy Hill Road	Bridge	79%[2]	NA	Fully Compatible	Deposition below	Low
	M20	Moulton Lane	Bridge	100%[4]	NA	Mostly Compatible	Deposition above	NR
	M20	Sterling Valley Road	Bridge	Not available	NA	No assessment data available	Deposition above, deposition below	Low
	M21-B	Dr Neel Road	Bridge	67%[3]	NA	No assessment data available	Scour below	Low
Miller Brook	T4.01	Moscow Road	Bridge	56%[2]	NA	Partially Compatible	Deposition above and below; scour above and below	Moderate
	T4.02	Nebraska Valley Road	Bridge	79%[2]	NA	Partially Compatible	Deposition above, scour above and below, alignment (bridge appears to be in poor condition)	Moderate
	T4.03-A	Nebraska Valley Road	Bridge	88%[2]	NA	Partially Compatible	Deposition above and below, scour above, alignment	Moderate

Table 5
Little River Watershed
Evaluation using VANR Geomorphic Compatibility and AOP Screening Tools

Stream Name	Reach/ Segment Number	Road Name	Structure Type	Percent Bankfull Channel Width[1]	Aquatic Organism Passage (AOP)	Geomorphic Compatibility	Phase 2 Constriction Notes	Priority for Replacement or Retrofit
	T4.03-A	Miller Brook Road	Bridge	110%[2]	NA	No assessment data available	Deposition above	NR
	T4.05	Nebraska Valley Road	Bridge	46%[2]	NA	Partially Compatible	Deposition below and scour above	Moderate
Gold Brook	T6.01	Waterbury Road	Bridge	91%[4]	NA	Partially Compatible	Deposition below; top of structure deteriorated	Moderate
	T6.02	Gold Brook Road	Bridge	186%[4]	NA	Mostly Compatible	Bridge is 50 feet high	NR
	T6.03-D	Covered Bridge Road	Bridge	108%[2]	NA	Mostly Compatible	None	NR
	T6.05	Stowe Hollow Road	Bridge	135%[2]	NA	Mostly Compatible	Deposition above, deposition below, alignment	Low
	T6.05	Upper Hollow Road	Culvert	65%[2]	No AOP except adult salmonids	Fully Compatible	Deposition above and below, scour below	High
	T6.05	N Hollow Road	Bridge	69%[2]	NA	Mostly Incompatible	Deposition above, deposition below, scour below	Moderate
	T6.06-A	Bryan Road	Culvert	37%[2]	Reduced	Mostly Compatible	Deposition above, deposition below, scour below (steep riffle and undersized)	Moderate
	T6.07	N Hollow Road	Culvert	42%[2]	Reduced	Mostly Compatible	Deposition above, deposition below, scour below; possible fish passage issue	Moderate
Moss Glen Brook	T8.01-A	Stagecoach Road	Twin Culverts	56%[4]	Reduced	Mostly Incompatible	Deposition above and below, scour below	High
	T8.01-A	Pucker Street	Bridge	175%[2]	NA	No assessment data available	Deposition above	NR

[1]Shaded for bankfull width percentage less than 50%, [2]Percent bankfull width measured in the field during Phase 2 Assessment, [3]Percent bankfull width based on Vermont Hydraulic Geometry Curves, [4]Structure width from VANR Bridge and Culvert Assessment, [5]NR- not recommended for replacement or retrofit at this time

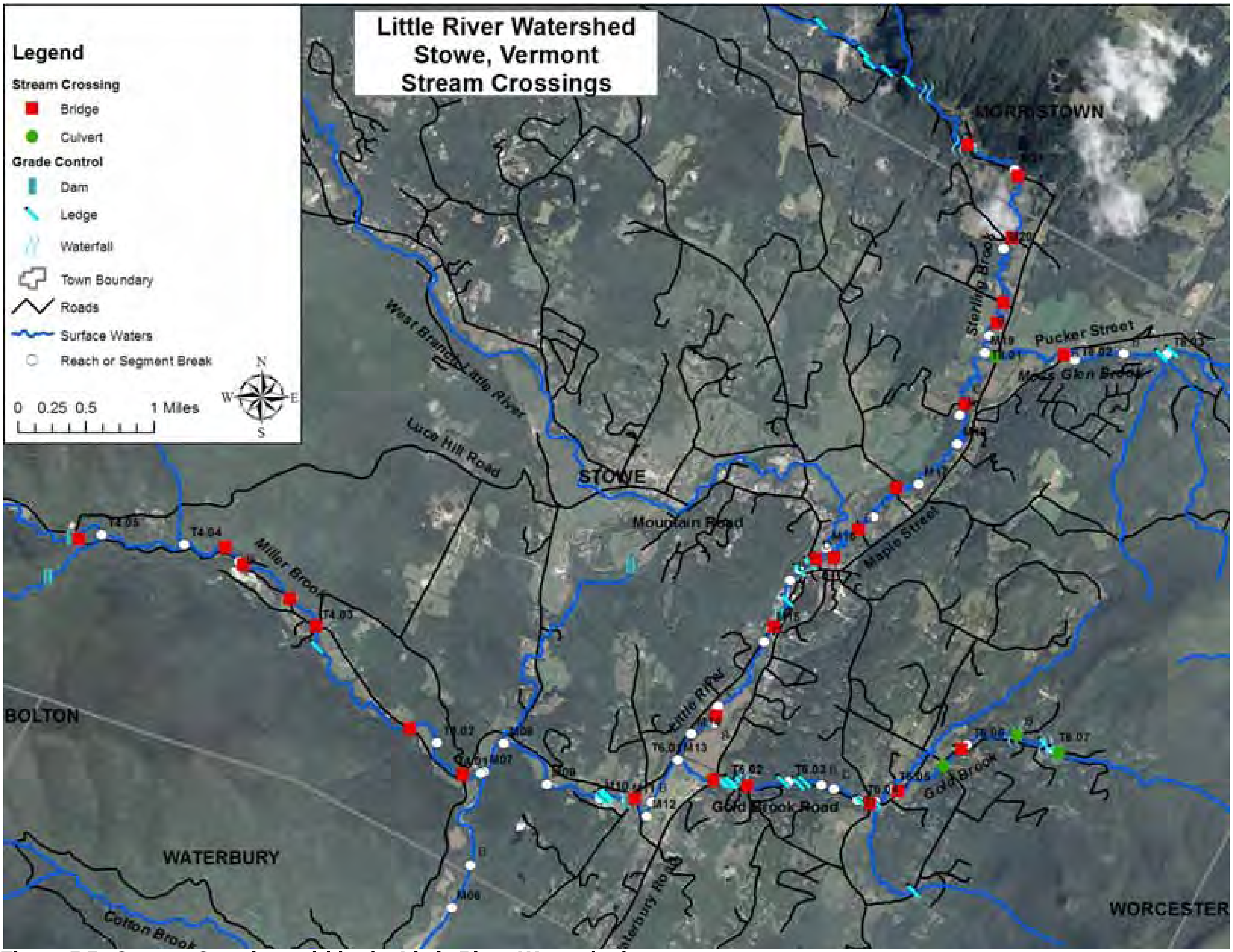

Figure 5.5. Stream Crossings within the Little River Watershed

6.0 Stressor, Departure and Sensitivity Analysis

Stressor, departure and sensitivity maps are presented here as a means of displaying the effects of all significant physical processes occurring within the Little River watershed that were observed during the Phase 1 and Phase 2 Stream Geomorphic Assessments. These maps also provide an indication of the degree to which the channel adjustment processes within the watershed have been altered, at both the watershed scale and the reach scale. The analysis of existing and historic departures from equilibrium conditions along a stream network allows for the prediction of future alterations within the watershed. This is helpful in developing and prioritizing potential protection and restoration projects.

6.1 Stressor Identification

6.1.1 Hydrologic Regime Stressors

The hydrologic regime is the timing, volume, and duration of flow events throughout the year and over time and is characterized by the input and manipulation of water at the watershed scale. When the hydrologic regime has been significantly changed, stream channels will respond by undergoing a series of channel adjustments. The land use within the watershed plays a role in the hydrology of the receiving waters. The percentage of urban and cropland development within the watershed are factors which change a watershed's response to precipitation. The most common effects of urban and cropland development is increasing peak discharges and runoff by reducing infiltration and travel time (United States Department of Agriculture 1986).

The dominant watershed land cover/land use within the Little River watershed is forest. The two most downstream reaches on Gold Brook were the only Phase 2 reaches which resulted in a watershed land cover/land use impact rating of high (10% or more is crop and/or urban). Analysis of hydric soils located where current land uses are agricultural or urban indicates some loss of wetland attenuation (Figure 6.1). Historical deforestation in the Little River watershed may also have contributed to wetland loss.

The Little River watershed has a moderate network of roads as shown in Figure 6.1. Extensive road networks can contribute significantly to increased flows within a river resulting both from increased runoff and stormwater ditching. According to Foreman and Alexander (1998), increased peak flows in streams may be evident at road densities of 3.2 miles/ square mile. Subwatersheds with road densities of greater than 3.2 miles/ square mile account for about 13 percent of the Little River watershed. The highest road densities within the watershed are along the lower end of Stevenson Brook, Gold Brook and along Moss Glen Brook.

6.1.2 Sediment Regime Stressors

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 regime, and the specific morphology of the valley, floodplain, and stream. The Sediment Load Indicators Map (Figure 6.2) shows the distribution of sediment load indicators in the study area. Figure 6.2 also shows the cumulative percentage of agricultural land (based on the percentage of cropland) for each subwatershed. As discussed in Section 3.1.3. Land Use, the Little River watershed is 77 percent forest, 9 percent agriculture, 4 percent developed and urban, 8 percent water and 1 percent wetland.

Bank erosion and mass failures contribute significant sediment inputs within the Little River watershed. Bank erosion is defined as "an area of raw and barren soils where the vegetation does not have the ability to hold the soil and/or the soil has slumped or fallen into the channel". Mass failures can occur when "a perennial stream erodes into or undercuts a high erodible landform, such as glacial lacustrine terrace" (Vermont Agency of Natural Resources, 2007b). Bank erosion mapped during the Phase 2 study totals approximately 27 percent on both the east and west banks of the 48 reaches assessed. Nineteen mass wasting sites were mapped during the Phase 2 assessment. The total length of mass failures on the Little River Phase 2 reaches is about 1,200 feet. Mass failures are most prevalent on Gold Brook. The Gold Brook reaches account for about 15 percent of the mass failures by length of the Phase 2 study area.

Depositional features per mile are mapped to show areas of deposition and planform adjustment. Steep riffles, mid-channel bars, delta bars, flood chutes, avulsions and braiding are parameters included in the depositional features' map layer. This layer does not necessarily explain the sources of sediment, but these depositional and channel bifurcation features are common in areas where the sediment transport capacity of the channel has been exceeded (VANR, 2007a). Channel migration features (avulsions and flood chutes) are included on the map to show areas of significant planform adjustment. Over 80 percent of the Phase 2 segments assessed have a high number (greater than 5) of depositional features per mile. The most downstream segment assessed for Phase 2 (M06-B) is the only reach with a moderate (between 2 and 5) number of depositional features per mile. Eight segments have a low (less than 2) number of depositional features per mile.

The high bank erosion and the prevalence of mass failures illustrate the Little River has a high source of sediment input. This is resulting in the channel being overwhelmed by sediment and exceeding the sediment transport capability as observed by the numerous depositional features per mile. The high level of aggradation is especially evident in T6.03-B on Gold Brook where there are multiple depositional features and a channel evolution stage of D-IId.

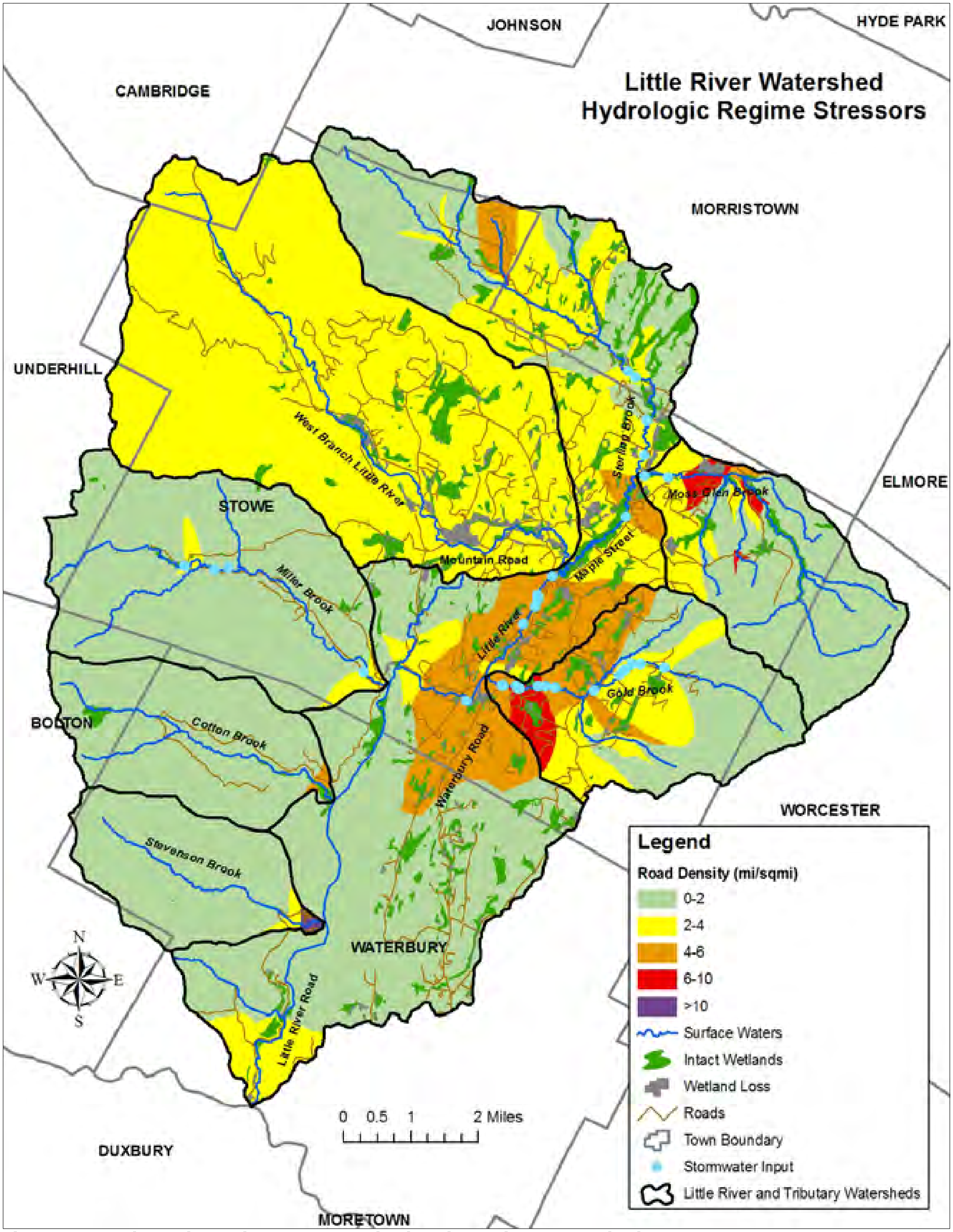

Figure 6.1 Hydrologic Regime Stressors in the Little River watershed.

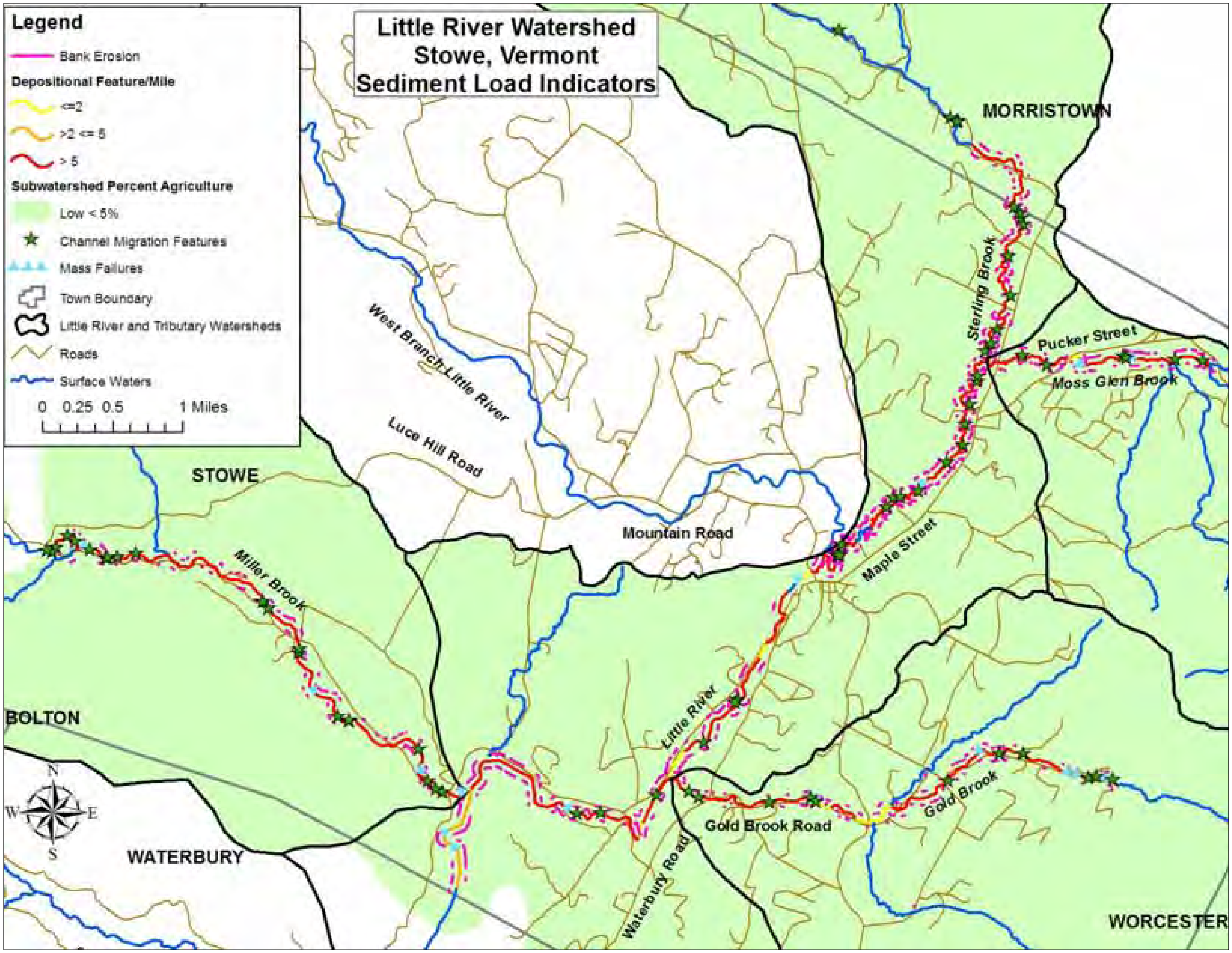

Figure 6.2. Sediment load indicators map for the Little River in Stowe.

6.1.3 Channel Modifiers

Channel straightening, floodplain encroachment, and berms and roads can increase the slope of a channel resulting in increased stream power. Increases in stream power (shown in red or orange in Figures 6.3 and 6.4) can initiate streambed erosion resulting in incision. The most extensive areas of channel straightening and floodplain encroachment (both development and adjacent berms and roads) are in the middle of the watershed between reaches M08 and M15 (Figures 6.3 and 6.4). The Little River within these reaches runs predominantly along Moscow Road and River Road. The majority of the channel straightening within the Little River watershed is associated with roads that run parallel to the stream. The extensive areas with increases in stream power explain the high degree of channel adjustment that is occurring within the watershed.

Grade controls (waterfalls and ledge) and natural and manmade dams and constrictions (such bridges and culverts) constrict flows or raise the bed elevation. Backwater conditions and sediment deposition typically reduce channel slope and stream power (Vermont Agency of Natural Resources, 2007a). Localized areas where slope decreases are expected in the Little River watershed are shown in blue and green in Figures 6.3 and 6.4.

6.1.4 Boundary Conditions and Riparian Modifiers

The resistance of the channel boundary materials is important for understanding the sensitivity of a channel and for predicting when a channel will undergo adjustment from stressors in the watershed. There are a number of factors that can result in decreased boundary condition. One of the most important factors is the quality of the riparian buffer. Riparian buffers provide many benefits. Some of these benefits are protecting and enhancing water quality, providing fish and wildlife habitat, providing streamside shading, and providing root structure to prevent bank erosion. Woody vegetation is essential for holding the bank soils to provide resistance to streambank erosion. There are many locations along the Little River mainstem, Gold Brook and Miller Brook where there is little or no buffer as defined by buffers less than 25 feet in width (Figures 6.5 and 6.6). These stream reaches which lack a high quality riparian buffer are at a significantly higher risk of experiencing high rates of lateral erosion.

Parameters which are indicative of a decrease in boundary condition are shown in red and orange in Figures 6.5 and 6.6. While bank armoring may temporarily increase the boundary condition, it is indicative of where the stream power has resulted in bank erosion or widening of the channel. Extensive bank erosion may increase the stream power, resulting in downstream bank erosion. Areas where woody debris, bed substrate and plant material were removed from the channel also result in decreased stream power. Gravel mining is a practice that can significantly decrease the boundary resistance. General areas where gravel mining has taken place were mapped by the LCPC during the Phase 1 portion of the study based on information provided by Vermont Agency of Natural Resources.

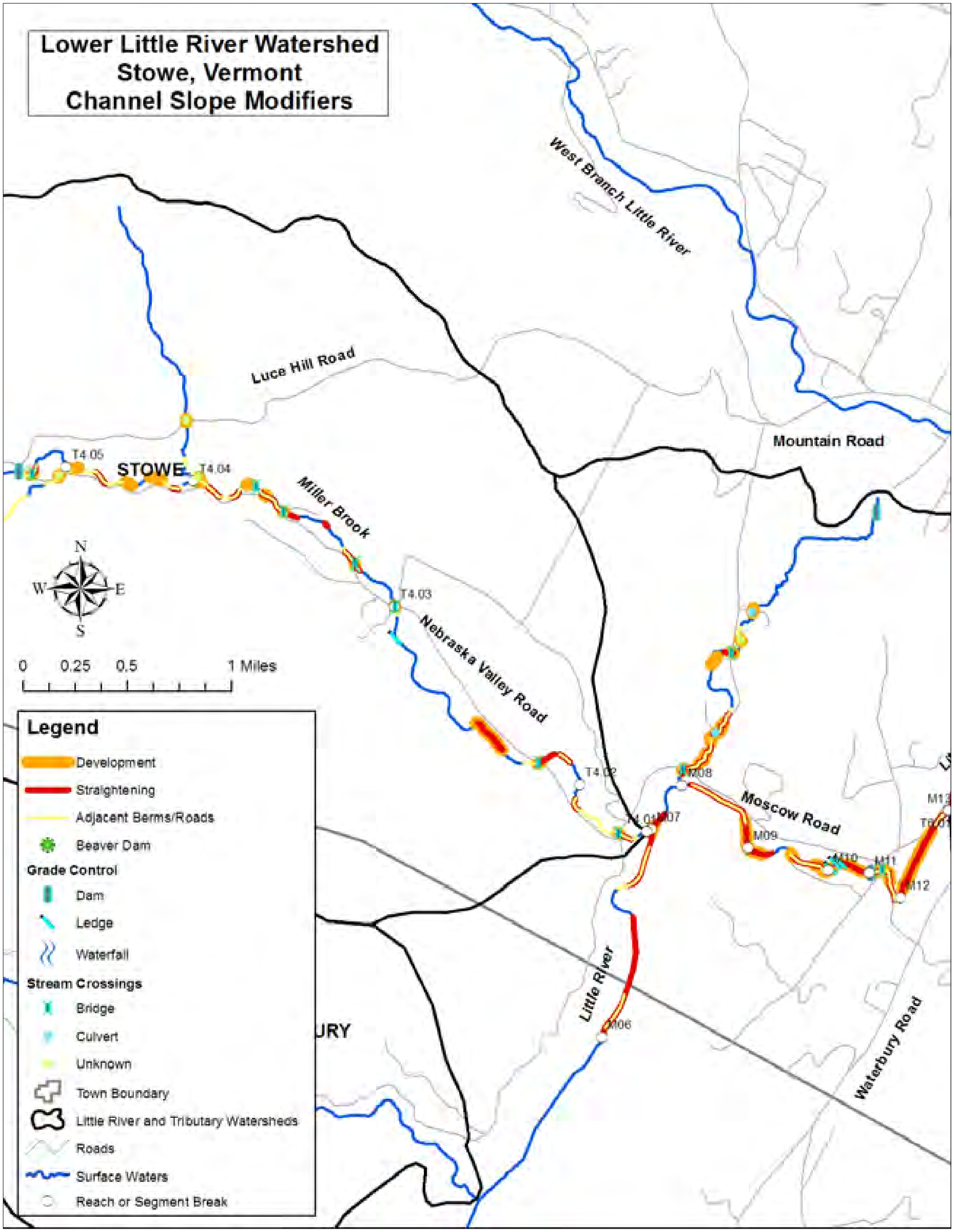

Figure 6.3. Channel slope modifiers map for lower Stowe showing parameters contributing to increases (red and orange) or decreases (blue and green) in slope.

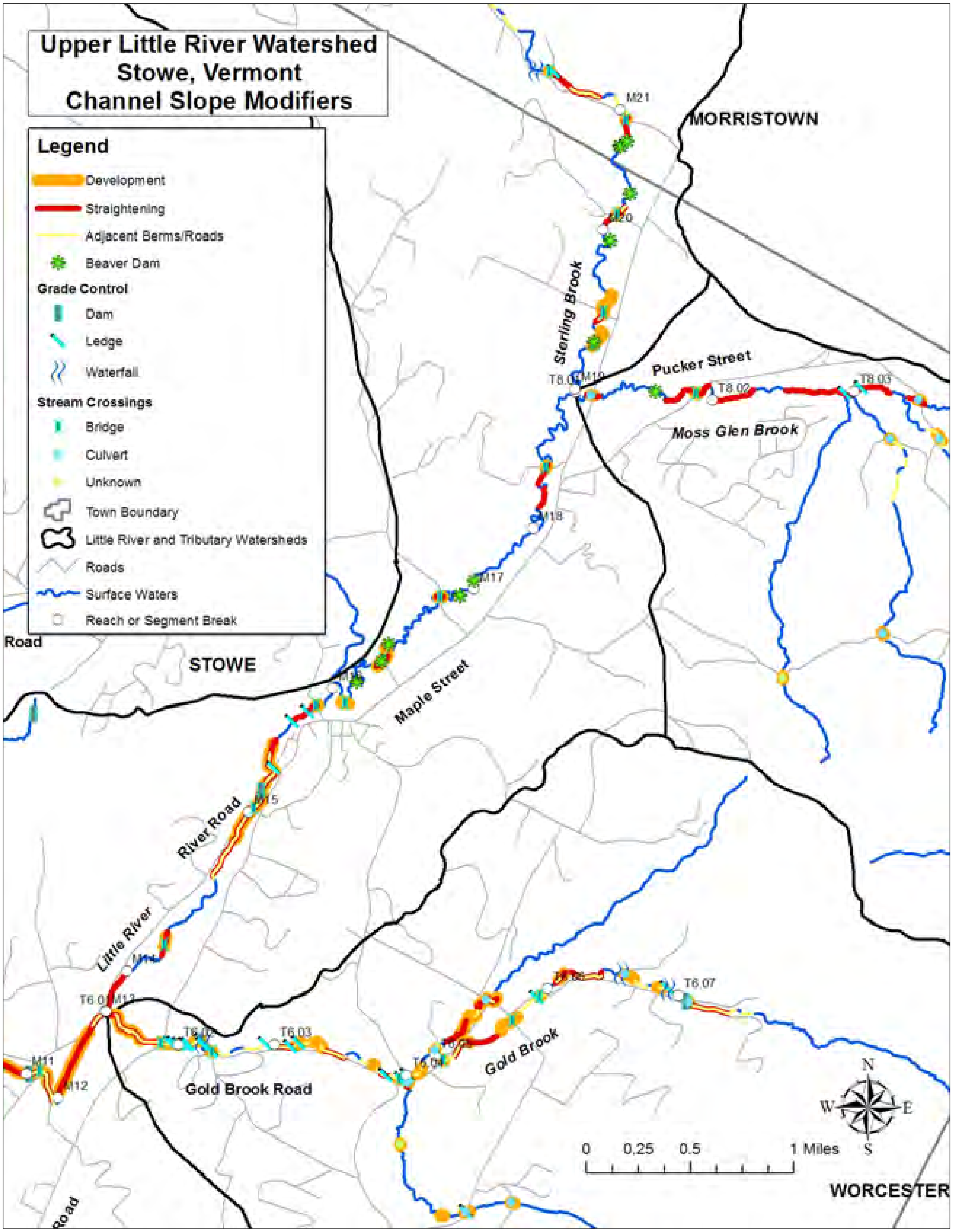

Figure 6.4. Channel slope modifiers map for upper Stowe showing parameters contributing to increases (red and orange) or decreases (blue and green) in slope.

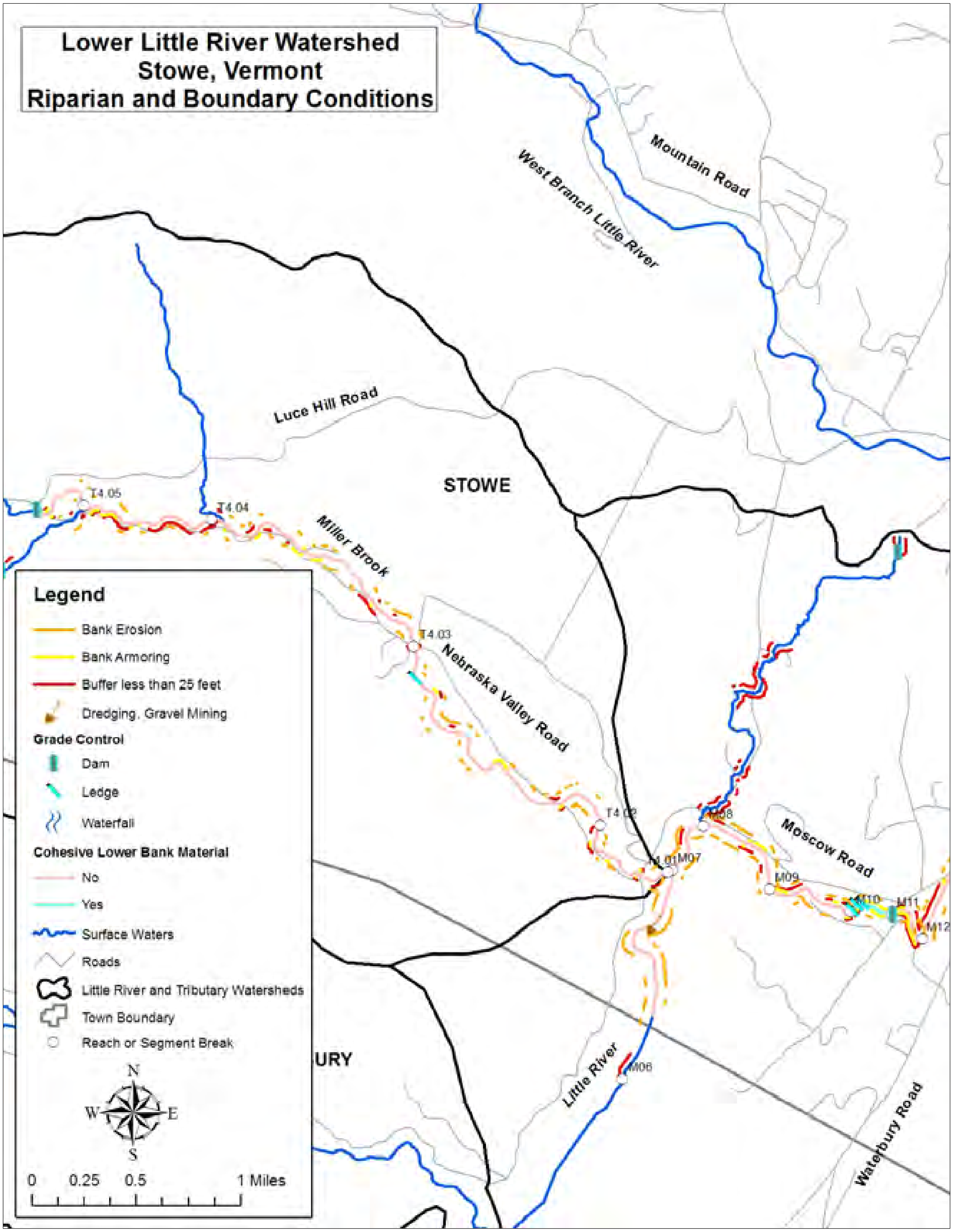

Figure 6.5. Boundary conditions and riparian modifications map for lower Stowe showing areas of decreased boundary condition (red and orange) and increased boundary condition (aqua).

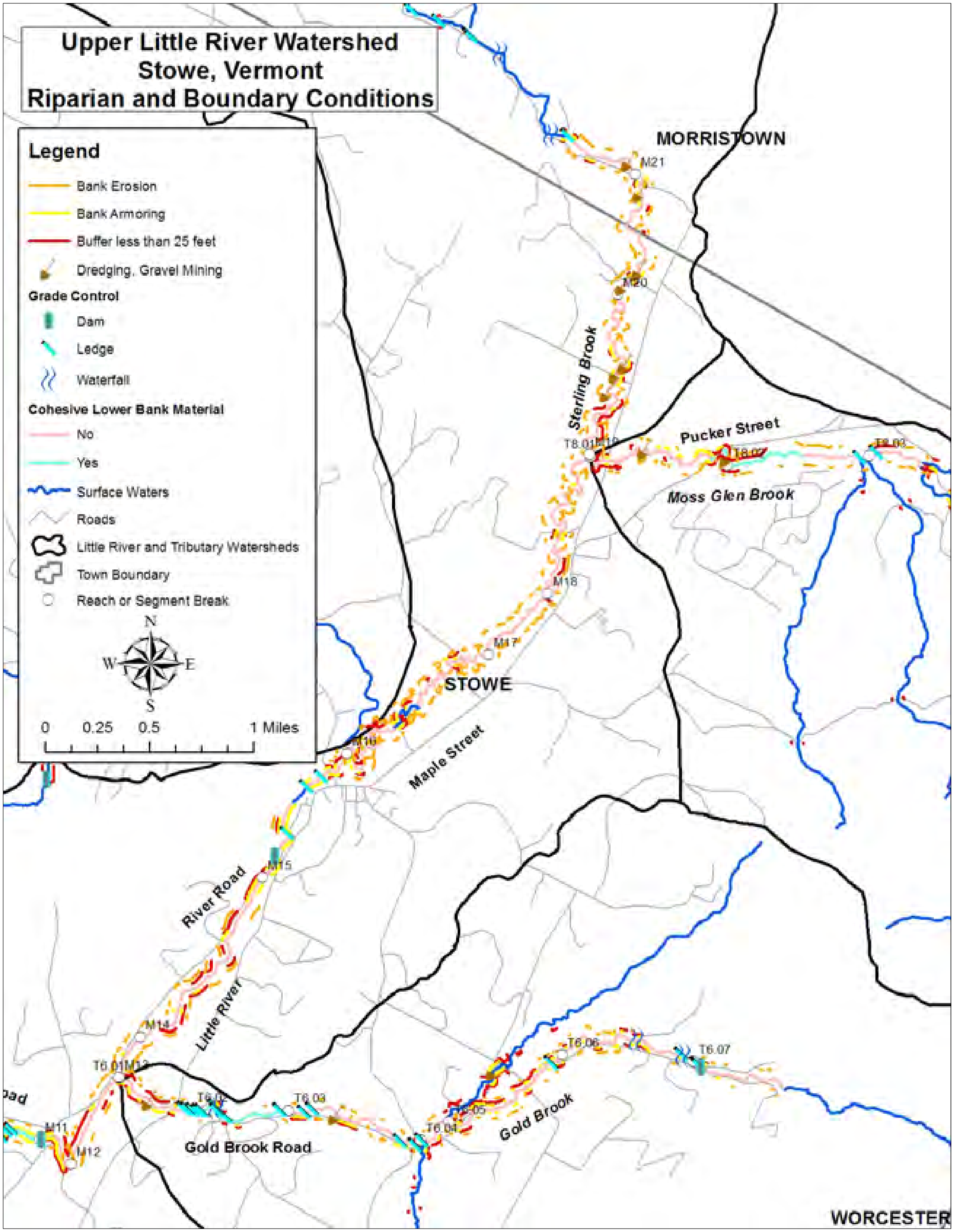

Figure 6.6. Boundary conditions and riparian modifications map for upper Stowe showing areas of decreased boundary condition (red and orange) and increased boundary condition (aqua).

Important factors that result in an increase in boundary condition are included in Figures 6.5 and 6.6 with aqua colored symbols. Natural and man-made grade controls increase the resistance of the bed to erosion. There were several locations where natural grade controls (ledge) were mapped based on the Phase 2 fieldwork including Miller Brook, mainstem of the Little River, Gold Brook and Moss Glen Brook. The cohesiveness of the lower bank materials is another factor that was considered in evaluating boundary resistance. Cohesive bank material can increase the boundary condition. The following areas had cohesive lower banks: middle section of the Little River main stem (M10), lower Gold Brook upstream of the Waterbury Road crossing (T6.02), and lower Moss Glen Brook above Pucker Street (T8.01-B and T8.02-A).

6.2 Departure Analysis

Successful river corridor restoration and protection projects depend on a thorough understanding of the sources, volumes, and attenuation of flood flows and sediment loads within the stream network. If increased loads are transported through the network to a sensitive reach, where conflicts with human investments are creating a management expectation, little success can be expected unless the restoration design accommodates the increased load or finds a way to attenuate the loads upstream (Vermont Agency of Natural Resources, 2007a).

Within a reach, the principles of stream equilibrium dictate that stream power and sediment will tend to distribute evenly over time (Leopold, 1994). Changes or modifications to watershed inputs and hydraulic geometry create disequilibrium and lead to an uneven distribution of power and sediment. Large channel adjustments observed as dramatic erosional and depositional features may be the result of this uneven distribution of power and sediment, and these adjustments may continue until a state of equilibrium is reached.

The analysis of sediment regimes at the watershed scale is useful for summarizing the stressors affecting the equilibrium condition of river channels. Sediment regime mapping provides a context for understanding the sediment transport and channel evolution processes which govern changes in geometry and planform for river channels in a state of disequilibrium. Sediment Regime Maps have been prepared to show departure from reference conditions due to human alterations.

The reference sediment regime map (Figure 6.7) shows the Phase 1 reference stream sediment conditions for each reach within the stream network. In the reference condition, streams use available floodplain access as a means to store sediment within the watershed. With one exception, all segments of the Phase 2 study area have a reference sediment regime of Coarse Equilibrium & Fine Deposition (*Equilibrium*) or Transport. The majority of the stream network has a reference sediment regime of *Equilibrium*. *Equilibrium* channels are unconfined on at least one side, and they transport and deposit sediment in equilibrium, wherein the stream power is balanced by the sediment load, sediment size, and channel boundary resistance. *Transport* channels, on the other hand, are steep, dominated by bedrock and boulder/cobble substrates, and are typically in confined valleys. Transport channels do not supply appreciable quantities of sediments to downstream reaches (Vermont Agency of Natural Resources, 2007a). Reach M13 has a reference regime of *Confined Source and Transport.* These channels have confining valleys walls with limited sediment storage capacity due to both channel slope and entrenchment (Vermont Agency of Natural Resources, 2007a).

Changes in hydrology (such as development and agriculture within the riparian corridor) and sediment storage within the watershed have altered the reference sediment regime types for some reach segments. All departures were derived from the DMS according to the sediment regime criteria established by the Vermont Agency of Natural Resources (2007a). Existing sediment regimes have not been established for reaches that were not assessed during the phase 2 stream geomorphic assessment. Many segments that were *Coarse Equilibrium (in=out) & Fine Deposition* type segments by reference have been converted to *Fine Source and Transport & Coarse Deposition* sediment regimes based on the Phase 2 Stream Geomorphic Assessment data (Figure 6.8). This means that most fine sediment entering the stream is transported through without being deposited as a result of channel incision and reduced floodplain access. Additionally, coarse sediment storage is increased due to increased load along with lower transport capacity.

The existing sediment regime for the Little River watershed includes reduced floodplain access, increased stream power, reduced boundary resistance, and lateral constraints, such as roads, at various locations throughout the stream network. Watersheds which 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 (Vermont Agency of Natural Resources, 2007a).

6.3 Sensitivity Analysis

Stream sensitivity refers to the likelihood that a stream will respond to a watershed or local disturbance or stressor, such as: floodplain encroachment, channel straightening or armoring, changes in sediment or flow inputs, and/or disturbance of riparian vegetation (Vermont Agency of Natural Resources, 2007b).

Assigning a sensitivity rating to a stream is done with the assumption that some streams, due to their setting and location within the watershed, are more likely to be in an episodic, rapid, and/or measurable state of change or adjustment. A stream's inherent sensitivity may be heightened when human activities alter the characteristics that influence a stream's natural adjustment rate including: boundary conditions; sediment and flow regimes; and the degree of confinement within the valley. Streams that are currently in adjustment, especially those undergoing degradation or aggradation, may become acutely sensitive (Vermont Agency of Natural Resources, 2007b). Stream sensitivity is assigned based on the existing stream type and condition. For a particular stream type, a segment in "reference" or "good" condition has a lower sensitivity than a reach in "fair" condition. The highest sensitivity is assigned for segments in "poor" condition and reaches which have undergone a stream type departure.

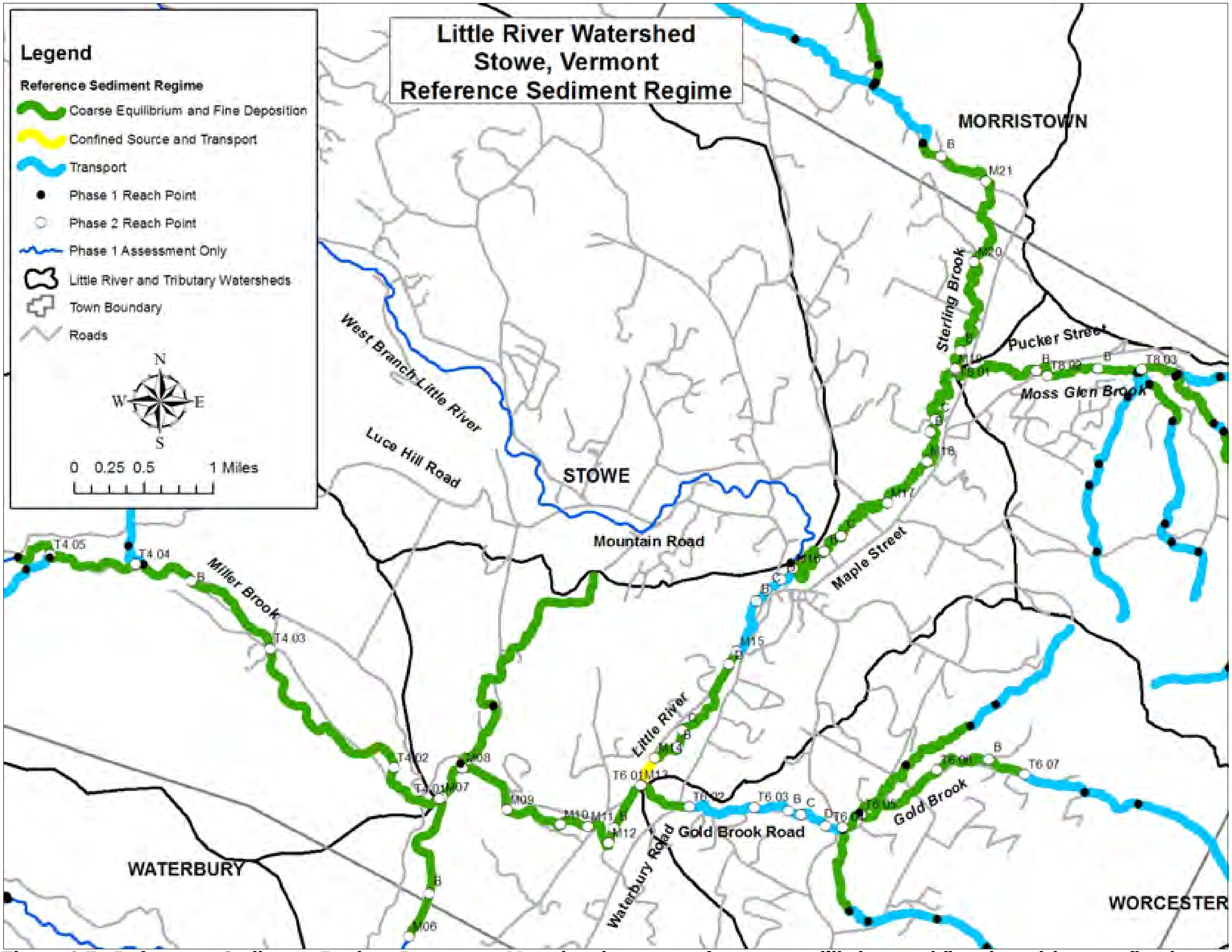

Figure 6.7. Reference Sediment Regime Departure Map showing areas of coarse equilibrium and fine deposition, confined source and transport, and transport reaches.

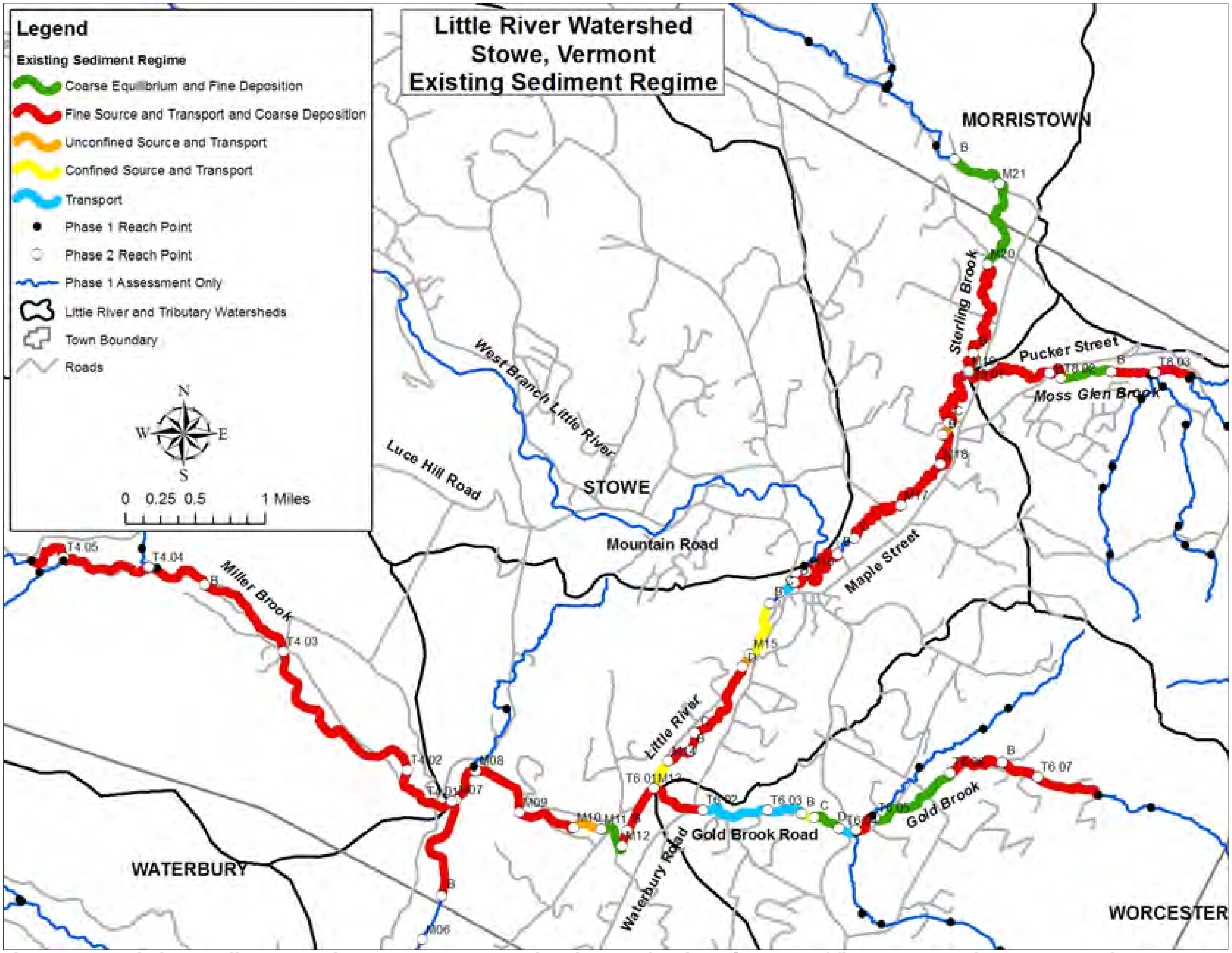

Figure 6.8. Existing Sediment Regime Departure Map showing predominantly areas of fine source and transport and coarse deposition reaches

There are many variables that are contributing to the sensitivity of the reaches in the Little River watershed. The lack of bedrock and cohesive lower banks decrease the resistance to lateral and vertical adjustments; thereby, making the channel more sensitive. Additionally, bank vegetation and roots which hold the soil are lacking especially in the middle section of the Little River main stem and along Gold Brook and Miller Brook. Reaches that are lacking high quality riparian vegetation are more sensitive to channel adjustment.

The location and slope of a stream also affects its morphology and sensitivity. Streams that are transporting sediment through the channel are less sensitive than streams that are storing and responding to sediment. Low gradient streams, like the Little River, with high sediment supplies are very sensitive and may undergo adjustment following minor changes in channel geometry or boundary condition. Additionally, flow regime and floodplain constrictions may be affecting the sensitivity of the Little River watershed. Changes in land use and land cover that increase impervious cover, peak discharges, and/or the frequency of high flows will heighten a stream's sensitivity to change and adjustment. Confinement becomes a significant sensitivity concern when structures such as roads, railroads, and berms significantly change the confinement ratio, reduce or restrict a stream's access to floodplain, and result in higher stream power during flood stage.

Figure 6.9 is a map presenting the stream sensitivity, generalized according to stream type and condition as per the VANR protocol, and current adjustments for each reach segment in the Little River watershed. Sensitivity ratings have not been assigned for bedrock dominated segments and impounded segments that were not assessed. Segments M08 (lower Little River mainstem), T4.02 (lower Miller Brook), T8.02-B, and T8.03 (lower Moss Glenn Brook) are gravel dominated segments that have undergone a stream type departure from a reference "C" channel to an "F" channel. This has resulted in a change in sensitivity from high to extreme (Figure 6.9). Segments T6.03-B and T6.07 (on central and upper Gold Brook, respectively), are gravel dominated segments that have also undergone a sensitivity change (moderate to extreme) because of a stream type departure from a "B" channel to an "F" channel. These stream type departures are attributed to historic incision. Major aggradation adjustment processes are displayed on the corridor where they were found to be actively occurring and not evaluated as historic. Aggradation is a current major active process for many Little River main stem reaches, the three most downstream reaches on Miller Brook, most reaches on Moss Glen Brook, and one reach on Gold Brook. This information is useful in prioritizing the implementation of the projects identified in Section 7 of this report, as certain management actions may be influenced by these active adjustment processes.

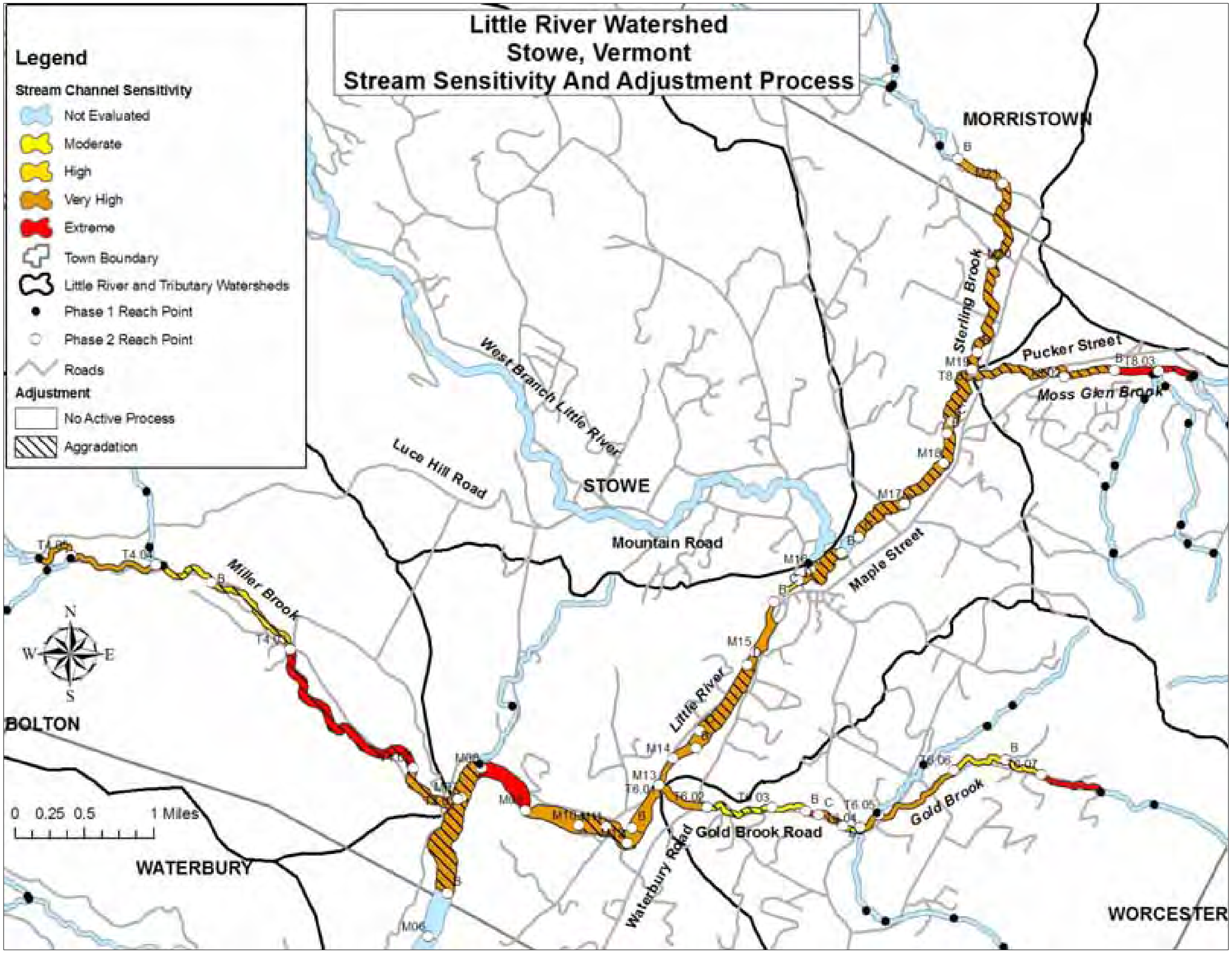

Figure 6.9. Stream sensitivity and current adjustment of the Little River

7.0 PRELIMINARY PROJECT IDENTIFICATION AND PRIORITIZATION

The departure and sensitivity analyses presented in Section 6.0 of this report provide beneficial background for selecting potential projects that will effectively help the channel return to equilibrium conditions by assessing limiting factors and by identifying underlying causes of channel instability. The stream reaches evaluated in this study present a variety of planning and management strategies which can be classified under one of the following categories: Active Geomorphic Restoration, Passive Geomorphic Restoration, and Conservation.

Active Geomorphic Restoration implies the management of rivers to a state of geomorphic equilibrium through active, physical alteration of the channel and/or floodplain. Often this approach involves the removal or reduction of human constructed constraints or the construction of meanders, floodplains or stable banks. Active riparian buffer revegetation and long-term protection of a river corridor is essential to this alternative.

Passive Geomorphic Restoration allows rivers to return to a state of geomorphic equilibrium by removing factors adversely impacting the river and subsequently using the river's own energy and watershed inputs to re-establish its meanders, floodplains and equilibrium conditions. In many cases, passive restoration projects may require varying degrees of active measures to achieve the ideal results. Active riparian buffer revegetation and long-term protection of a river corridor is also essential to this alternative.

Conservation is an option to consider when stream conditions are generally good and nearing a state of dynamic equilibrium. Typically, conservation is applied to minimally disturbed stream reaches where river structure and function and vegetation associations are relatively intact.

There are a number of voluntary programs available for river protection. Two of the primary programs are the Conservation Reserve Enhancement Program (CREP) and the River Corridor Easement (RCE). CREP is a program that helps protect environmentally sensitive land, decrease erosion, and restore wildlife habitat by taking land out of agricultural production. An overview of the Conservation Reserve Enhancement Program is found at http://www.fsa.usda.gov/FSA/webapp?area=home&subject=lown&topic=cep. 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. A description of each of the programs prepared by the Vermont River Management Program is provided below.

Conservation Reserve Enhancement Program

- 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.

River Corridor Easement (RCE)
- 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 management plan accompanies the easement outlining the management and land use practices expected to occur within the corridor and describe any accommodations that must be made for existing structures (e.g. outbuildings, stream crossing, etc.).
- 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.

7.1 Watershed-Level Opportunities

Fluvial Erosion Hazard Zones

Of all types of natural hazards experienced in Vermont, flash flooding represents the most frequent disaster mode and has resulted in by far the greatest magnitude of damage suffered by private property and public infrastructure. While inundation-related flood loss is a significant component of flood disasters, the predominant mode of damage is associated with the dynamic, and oftentimes catastrophic, physical adjustment of stream channel dimensions and location during storm events due to bed and bank erosion, debris and ice jams, structural failures, flow diversion, or flow modification by man-made structures. These channel adjustments and their devastating consequences have frequently been documented wherein such adjustments are related to historic channel management activities, floodplain encroachments, adjacent land use practices and/or changes to watershed hydrology associated with land use and drainage.

The purpose of defining Fluvial Erosion Hazard Zones is to prevent increases in fluvial erosion resulting from uncontrolled development in identified fluvial erosion hazard areas; minimize property loss and damage due to fluvial erosion; prohibit land uses and development in fluvial erosion hazard areas that pose a danger to health and safety; and discourage the acquisition of property that is unsuited for the intended purposes due to fluvial erosion hazards. The basis of a Fluvial Erosion Hazard Zone is a defined river corridor which includes the course of a river and its adjacent lands. The width of the corridor is defined by the lateral extent of the river meanders, called the meander belt width, which is governed by valley landforms, surficial geology, and the length and slope requirements of the river channel. The width of the corridor is also governed by the stream type and sensitivity of the stream. River corridors, as defined by the Vermont Agency of Natural Resources (2008), are intended to provide landowners, land use planners, and river managers with a meander belt width which would accommodate the meanders and slope of a balanced or equilibrium channel, which when achieved, would serve to maximize channel stability and minimize fluvial erosion hazards. Information collected during the Phase 2 Assessment including reach sensitivity, reach condition, and stream type is used to develop these zones. Towns have the opportunity to work with the Vermont River Management Program to develop fluvial erosion hazard zones to reduce conflicts within the river corridor.

STORMWATER

Stormwater runoff rates are of particular concern in urbanized and agricultural watersheds because stormwater runs off from impervious surfaces rather than naturally infiltrating the soil. The cumulative effect of the increased frequency, volume, and rate of stormwater runoff results in increases in wash-off pollutant loading to streams and destabilization of stream channels. All potential restoration projects within the Little River watershed should be evaluated in terms of their effects on stormwater.

7.2 Reach-Level Opportunities

A description of each reach/segment is provided in this section along with general recommendations for restoration and protection strategies. The reaches are listed from downstream to upstream. Further details about project types for each reach will be discussed in Section 7.3. The reaches are broken into sections based on the stream they are located in: Little River, Miller Brook, Gold Brook, and Moss Glen Brook.

Little River Section A: The Little River mainstem has three distinct sections. The lower 2.9 miles (M06 to M11) in general have channels with a very high width to depth ratio with moderate to severe incision. These reaches are predominantly located in a *Fine Source and Transport and Coarse Deposition* regime and are in stage F-III or F-IV of the channel evolution model. All of these reaches are gravel dominated “C” reaches by reference.

Reach M06

Little River reach M06 is 6,242 feet in length and begins just 1,800 feet downstream of the Stowe/Waterbury boundary. The river corridor of reach M06 lies completely with the Mount Mansfield State Forest. The lower section M06-A was not assessed since it was influenced by the downstream Waterbury Reservoir. Segment M06-B begins at the Stowe/Waterbury boundary and continues north 4,418 feet until the confluence with Miller Brook. M06-B has a very broad valley and a very high width to depth ratio. As shown in Figures 7.1 and 7.2, Segment M06-B has a wide depositional channel as shown by large side bars. Erosion is common along both banks, especially on meander bends, and there are two mass failures within Segment M06-B (Figure 7.1). Forest is the dominant land use on both sides of the corridor and hay is the sub-dominant land use within the west corridor. There are areas that have been mined for gravel on the large side bars (Figure 7.2). The channel has been extensively straightened for agriculture, which most likely led to its incision and subsequent widening. There is a minor change in channel confinement in this segment from nearby Cottonbrook Road, but no change in valley type.

Figure 7.1. Large side bar and mass failure in Segment M06-B

Figure 7.2. Another large side bar in Segment M06-B

Segment M06-B is a "C" gravel dominated segment. The rapid geomorphic assessment (RGA) scored in the "fair" category due to the major historic degradation, major widening and aggradation, and minor planform adjustment. The reference channel width is 92 feet, but the bankfull width in the cross section was measured as 133 feet (Figure 7.3) indicating that the segment is over widened. The large depositional features are a result of the over widened channel. The rapid habitat assessment (RHA) rated in the "fair" category mostly due to deposition in the channel, channel straightening, and bank erosion.

Figure 7.3. Typical wide cross section in M06-B

Reach M07

M07 begins at the confluence with Miller Brook and extends upstream for 1,580 feet. With the exception of the upper end of reach M07, the river corridor includes and is surrounded by the Mount Mansfield State Forest. Forest is the dominant land use within the east corridor and the dominant land use within the west corridor is hay. The valley is slightly narrower than in M06 with a broad confinement. Like M06-B, M07 has a very high width to depth ratio. Reach M07 is severely incised and is in stage F-IV for channel evolution. About one-third of the channel length has been historically straightened for agriculture, which most likely led to its incision and subsequent widening and planform adjustment. There is a slight human caused change in valley confinement for this reach from Moscow Road, but no change in valley type.

The presence of a mid-channel bar, point bars and large side bars indicates that M07 is also depositional (Figure 7.4). Erosion is also common along both banks. The dominant buffer width on both sides of the channel is greater than 100 feet in width; however, about ¼ of the west bank has buffers less than 25 feet (Figure 7.5). These areas of minimal buffer are associated with hay fields. CREP is one possible program that could be used to improve water quality in Reach M07 by establishing buffers adjacent to hay fields.

Figure 7.4. Depositional features and wide channel in M07

Figure 7.5. Reach M07 has a significant lack of buffer causing bank failure.

The channel width in this gravel dominated “C” reach has deviated from its reference of 84 feet to 111 feet indicating major widening, which explains the deposition within the segment. The RGA rated in the “fair” category due to extreme historic degradation, and major aggradation, widening, and planform adjustment. Disturbance of natural conditions has impacted the habitat in this M07 resulting in a “fair” score for the RHA. The lack of vegetation on the western bank and within the riparian buffer, as well as bank erosion, contributed to the habitat condition. The east bank along reach M07 is providing higher quality habitat along than the west bank due to its well vegetated riparian buffer and protected banks.

Reach M08
Buffer Restoration

The total length of Reach M08 is 2,648 feet. The lower end of the reach begins at the confluence of Barrows Brook where the Little River turns to the east. The Stowe Land Trust owns close to a 50 acre parcel at the corner of Moscow Road and Barrows Road, called the Dumont property. The Dumont property abuts the Mt. Mansfield State Forest and a parcel owned by the Town of Stowe. In addition to providing opportunities for non-motorized outdoor recreation and wildlife habitat, the Dumont property affords additional protection to the Little River and Waterbury Reservoir watersheds. (Stowe Land Trust, 2008a). According to Tom Jackman, Director of Planning for the Town of Stowe (personal communication, 2010), a Japanese knotweed eradication project is being considered for the Dumont property. Japanese knotweed is an ornamental that was introduced for erosion control. This invasive plant spreads quickly to form dense thickets that exclude native plant species and the plant is of little value to wildlife (Van Driesche, R., et al., 2002). Japanese knotweed has inferior root structure compared with native plant species such as willows, dogwood and alders.

M08 has a narrow valley with no human-caused change in valley confinement. There is significant erosion on both banks of M08. Where Moscow Road comes close to the stream, rip-rap for bank stabilization is found along the north bank. Approximately ¼ of the southern bank and even less of the northern bank has a buffer width less than 25 feet. The majority of the reach has been straightened and is encroached by Moscow Road on the north side.

Reach M08 has experienced a stream type departure form a gravel dominated “C” stream to an “F” stream type due to the extreme historic incision. RGA rated in the “fair” category due to major widening and minor aggradation and planform adjustment. There are three steep riffles, some mid-channel bars and many side bars in M08 indicating that it is depositional. Pools have been filled in with sediment with the bed profile dominated by runs (Figure 7.6). The RHA also scored in the “fair” category as a result of extensive channel straightening, embedded bed substrate, unstable banks, and reduced riparian buffer. This reach would benefit from buffer restoration.

Figure 7.6. Long run in Reach M08

Reach M09
Buffer Restoration

Reach M09 starts on meander bend where Moscow Road is farther away from the channel and extends upstream 2,399 feet to the start of bedrock grade controls. The Dumont parcel owned by the Stowe Land Trust and town-owned property (stump dump) encompass much of the southern river corridor of the Little River in reach M09. The Moscow Recreation Field is part of the northern river corridor and includes 600 feet of frontage on the Little River. This 4.7 acre parcel is an open space used for activities such as baseball, swimming and picnicking. The Stowe Land Trust and the Vermont Housing and Conservation Board hold a conservation easement on the property with the Town of Stowe holding the title. (Stowe Land Trust, 2008b). Reach M09 runs along Moscow Road with development occurring within the river corridor on the north side. The valley confinement is broad and there is no human-caused change in valley width. Residential land use adjacent to Moscow Road dominates the riparian corridor on the north side, while forest dominates the corridor on the south. On the upstream end of the corridor on the south side, there is commercial land use.

Approximately half of the north bank has a buffer less than 25 feet in width, while the south bank has a dominant buffer width of greater than 100 feet. There is considerable bank erosion with approximately 30 percent erosion on each bank (Figure 7.7). A knotweed eradication project is currently underway at the Moscow Recreation Field (personal communication with Tom Jackman, 2010). There is a mass failure (12' high x 180' wide) on the upstream end of the reach on the south bank. The reach has been armored with rip-rap in some locations where there is no buffer and the reach has been straightened.

Many side bars, one mid-channel bar, two point bars, one diagonal bar, and one steep riffle were noted in the reach indicating that this reach is depositional (Figure 7.8). Reach M09 is a gravel dominated "C" channel in the F-III stage of channel evolution. The RGA scored "fair" due to extreme historic degradation and major widening and aggradation. Planform adjustment is a minor process. Channelization along Moscow Road, exposed substrates, deposition, bank erosion, and a narrow buffer width on the north bank are all factors that contributed to a RHA score of "fair".

Figure 7.7. Bank erosion along M09

Figure 7.8. Side bars in Reach M09

Reach M10

Reach M10 begins on the downstream end where there are bedrock grade controls (Figure 7.9) and commercial development within the corridor. The reach is 1,180 feet in length. The valley confinement is broad and there is no human-caused change in valley confinement. The corridor of reach M10 has considerable development along it with 60 percent of the north side developed and approximately 40 percent development on the south side. Straightening has occurred along approximately ¾ of the reach and the reach has been armored for about half its length with rip-rap along both banks.

Figure 7.9. Bedrock grade control in Reach M10

The dominant buffer width on both sides is 26 to 50 feet with a subdominant width of 0 to 25 feet. Residential land use is the dominant land use within both corridors. Low to moderate bank erosion was noted within the reach.

Multiple mid-channel bars, a diagonal bar and a steep riffle are present within the reach as well as some channel migration evident from a large flood chute. The geomorphic condition of the channel is "fair" based on the RGA. Reach M10 has experienced a stream type departure from a "C" channel to a "Bc" channel due to extreme historic incision. The dam located at the upstream end of reach M10 has most likely contributed to channel degradation (Figure 7.10). Aggradation is a major process in this reach and widening and planform adjustment are minor processes. The stream condition rating for both geomorphic condition and habitat is "fair". Channelization and narrow riparian buffers (26-50 feet on both banks) are all contributing to the fair habitat condition.

Figure 7.10. Dam at upstream end of M10

Reach M11
Bridge Replacement
Dam Removal

Reach M11 begins at the dam approximately 300 feet downstream of the bridge at Moscow Road (Figures 7.10 and 7.11) and continues 1,515 feet until just upstream of where the river bends away from Moscow Road. At this bend, a planned unit development (PUD) located on the south side of the Little River on the Salvas property has been approved with about 10 acres along the river as permanent open space (Personal communication with Tom Jackman, 2010). The Salvas property abuts the Nichols field , located in reach M12. The Stowe Land Trust has held a conservation easement on this field since 2004 (Stowe Land Trust, 2008c).

Figure 7.11. Bridge at Moscow Road in Reach M11

The west side of reach M11 has a buffer that is less than 25 feet for approximately ¾ of the reach and the other side has a buffer less than 25 feet for about half of its length. The subdominant buffer width is 26 to 50 feet. Residential land use is the dominant land use within the west corridor and pasture within the east corridor. There is limited bank erosion on the west bank due to the extensive bank armoring, but on the east bank there is approximately 30 percent bank erosion.

There is a human-caused change in valley confinement from broad to narrow due to the close encroachment of Moscow Road and Adams Mill Road along 1,345 feet of the west bank. Reach M11 has been extensively straightened. The west bank has been heavily armored with rip-rap along 70 percent of its length where it is very close to Moscow Road, while the east bank has rip-rap along 20 percent of its length.

Reach M11 contains many depositional features for its short length: three mid-channel bars, two side bars, one delta bar, one diagonal bar, and one steep riffle. Two islands indicate that the channel planform has been adjusting. The width to depth ratio is very high in M11 and the RGA was scored as “fair” due to its major aggradation and widening. Degradation and planform adjustment are minor in this reach. As a result of channel straightening, bank erosion, lack of riparian buffers and the decreased quality of channel substrate, the habitat has been affected with a RHA score of ”fair”.

Little River Section B: Section B includes segments M12-A through M15-D, where the channel is moderately incised and the existing stream type is the same as the reference stream type, with the exception of one segment. This 7.3 mile long section is a transition point between the severely incised downstream reaches and the upper depositional reaches. In general, section B is best characterized as stage II or III of the F channel evolution model with moderate historic incision and current minor aggradation, widening and planform adjustment in most downstream reaches. The processes in the upstream end include major aggradation and planform adjustment with minor to major widening. In many of the downstream reaches, the cross sections show that there is an old terrace at a higher elevation than the top of the bank.

Reach M12
Streambank Plantings

Reach M12 was broken into two segments due to depositional features and bedform. M12-B contains more depositional features than M12-A. M12-A has a plane bed bedform (Figure 7.12), while M12-B is predominantly riffle-pool.

Figure 7.12 Lack of bedform features in Segment M12-A

Segment M12-A begins at the sharp meander bend where Moscow Road is very close to the stream and continues past Gold Brook Campground upstream 598 feet where the valley width opens up. The valley confinement is broad and there is a human-caused change in channel confinement from River Road. It appears that the entire channel length was historically straightened.

The dominant buffer width of the east side is 26 to 50 feet, and over half of the west buffer is less than 25 feet in width. The west river corridor is mostly residential. Moderate to high scour and erosion was noted at the base of both banks, with more than half of the east bank eroded. Invasive vegetation covers both banks making M12-A vulnerable to erosion (Figure 7.13).

The dominant land use for the east river corridor is marked as hay, but it is actually lawn area from Gold Brook Campground and the Nichols field. The Nichols field abuts the river corridor at the southern end of the reach M12, and has about 1000 feet of river frontage. Vermont Electric Power Company (VELCO) is implementing a riparian planting plan for Nichols field (Personal communication with Tom Jackman, 2010).

Figure 7.13. Invasive vegetation on the banks of Segment M12-A

Segment M12-A is a gravel dominated “C” channel in stage III of the F evolution model. There is a lack of riffle-pool features (Figure 7.12). Extensive historic straightening has resulted in the downcutting of the bed leading to major historic degradation and plane bed features.

The current geomorphic processes in segment M12-A include minor widening, aggradation and planform adjustment. No depositional features were mapped in this segment. Both the RGA and RHA were rated as "fair condition". Extensive channel alteration, poor habitat diversity, unstable banks, and lack of riparian buffers contribute to the "fair" RGA score.

Segment M12-B is 1,969 feet in length and ends at the confluence with Gold Brook (T6.01). The segment is "C" gravel dominated, riffle-pool channel. There is a slight human-caused change in channel confinement but no change in valley type. The entire length has been straightened with armoring in a couple of short locations on each bank (Figure 7.14). Development occurs along 50 percent of one bank and 15 percent of both banks.

The dominant buffer width on the east bank is 26 to 50 feet and the dominant buffer width on the west bank is 51 to 100 feet. Both banks have a subdominant buffer width less than 25 feet. On the east bank the narrow buffer is due to the nearby campground and agricultural field, while the lack of buffer on the west bank is from residential lawns. Both corridors are mostly residential. Segment M12-B has minimal to moderate scour and erosion along both banks, with erosion along one-third of the west bank.


Figure 7.14. Typical straightened channel in M12-B

Depositional features are common within reach M12-B. Two steep riffles and one large flood chute was observed. As in M12-A, there is no major adjustment process in M12-B. The segment has experienced minor historic degradation with an incision ratio of 1.3. Both the geomorphic and habitat conditions were rated as "fair". Given the abundant channel straightening, depositional features, bank erosion (west bank) and limited riparian buffer (east side), the RHA was scored as "fair".

Reach M13
River Corridor Protection

Gold Brook (T6.01) enters the Little River just downstream of the reach break for M13. Reach M13 continues 1,195 feet along River Road and is straightened for the majority of the reach. River Road runs parallel to the river, but it is highly elevated above the valley wall and therefore does not encroach upon the corridor nor has there been a human caused change in channel confinement from the road (Figure 7.15). Reach M13 has a different reference stream type than reaches upstream and downstream from it. The reference and existing stream type is a semi-confined "B"


Figure 7.15. Elevated River Road along Reach M13

riffle-pool channel that is sand dominated. This channel is also in stage III of the F channel evolution model.

Most of the west bank within M13 has a riparian buffer width of 26 to 50 feet. On the east side of the river, the buffer width is predominantly 51 to 100 feet. Invasive vegetation is very common along banks and dominant within both buffers (Figure 7.16). Erosion is prevalent on both banks (about 50 percent on both sides) as a result of the poor root structure offered by the invasive vegetation. The dominant and subdominant land use within the west corridor is shrub/ sapling and forest, respectively. The eastern corridor is dominated by crops and also contains forest.

Figure 7.16. Invasive vegetation within both buffers in M13

The channel in reach M13 is moderately incised. The RGA scored “fair” with major historic degradation, widening and planform adjustment and minor aggradation. Reach M13 is overwide with moderate to high scour and erosion at the base of both banks. Moderate to high lateral bank erosion on most outside bends is also prevalent. The RHA also scored in the “fair” range due to a number of factors including the extensive channel straightening, sediment deposition within the channel, poor habitat diversity, bank erosion and lack of native vegetation on the banks.

<u>Reach M14</u>
Streambank Plantings
River Corridor Protection
Buffer Restoration
CREP

Reach M14 was broken up into four segments due to differences in depositional features, channel alteration, and valley width. Segment M14-A has not been straightened, while segment M14-B has undergone extensive channel modifications. Segment M14-C contains many more large depositional features than the other segments. Differences in valley width and stream type resulted in the segmentation of M14-D. This most upstream segment has experienced a stream type departure from a “C” to a “Bc” channel as a result of encroachment of River Road into the river corridor, causing a change in valley width.

The lowest segment, M14-A, is a gravel dominated “C” stream that is in stage III of an F

Figure 7.17. Typical channel in M14-A

type evolution. This 1,065 foot long segment begins where the Little River starts to meander again and then migrates away from River Road. In contrast to the adjacent segments, M14-A does not appear to have been historically straightened (Figure 7.17).

Herbaceous vegetation dominates the eastern buffer and deciduous trees are subdominant. The west side contains deciduous trees primarily, but there are also many invasive plants within the buffer. Dominant buffer widths for the east and west banks are less than 25 feet and greater than 100 feet, respectively. Land use within the eastern corridor is characterized mostly by hay fields with some forested areas. The west corridor is dominated by forest and shrub sapling is subdominant. The Stowe Land Trust holds a river corridor conservation easement in Stowe's lower village within reach M14. The project was funded through the State of Vermont River Management Program and the Stowe Conservation Commission. The corridor easement includes 2,000 feet of river frontage including floodplain and agricultural fields. (Stowe Land Trust, 2008d) Because of the major planform adjustment that is occurring within Reach M14, the acquisition of additional river corridor easements within this reach is recommended. Mary Nealon (2003) evaluated options for a restoration project using natural channel design principals on a section of river immediately upstream of the corridor easement referenced above. The Lamoille County Natural Resources Conservation District was responsible for acquiring funding for the project design work.

The channel is deep within M14-A. There is a very large point bar with a flood chute located in the upstream section. The historic incision along the Little River has also occurred within M14-A. The RGA scored "fair" due to major degradation and planform adjustment. Aggradation and widening are minor processes. The RHA was rated as "fair" due to the lack of areas for fish cover, increased substrate embeddedness, unstable banks, lack of vegetation, and a poor riparian buffer zone on the east bank.

Segment 14-B begins where the river channel has been historically straightened again for 675 feet. All of segment M14-B has been straightened for agricultural purposes. As with other segments in M14, M14-B is a gravel dominated "C" stream in stage F-III channel evolution, but unlike other segments, it has a plane bed bedform (Figure 7.18). The valley confinement is broad and there is no human caused change in channel confinement.

Figure 7.18. Typical channel in M14-B

Buffer vegetation within the east buffer is mostly invasive vegetation with deciduous trees subdominant. The western side contains primarily mixed trees with herbaceous vegetation. The dominant buffer width for the east side is less than 25 feet and on the west side it is primarily 26 to 50 feet wide and greater than 100 feet wide in some places. Land use within both corridors is predominantly hay and on the west side residential land use is subdominant. The areas of minimal buffer are associated with the hay fields. The water quality in the river could be improved by increasing the buffer widths along the hay fields through a streamside planting program such as CREP. There is erosion along both banks, but erosion is more prevalent on the east bank due to the lack of buffer and presence of invasive species. Approximately 20 percent of the east bank is armored with rip-rap.

The RGA was rated as “fair" due to the degradation and minor aggradation, widening and planform change. Segment M14-B has experienced major historic degradation leading to a weak riffle-pool channel with a bed profile that is dominated by runs. This lack of deep pools carries over to the habitat assessment as the RHA also rated as “fair”. The widespread channel straightening, unstable banks on the east side, and lack of riparian buffer also contribute to the “fair” habitat condition. Other factors influencing aquatic habitat in the segment are reduced fish cover and substrates for epifaunal colonization and excess sediment causing the substrate to be embedded.

Segment M14-C is another “C” stream and is the longest segment in reach M14 with a length of 3,466 feet. The segment begins where the river develops a meander pattern again and continues approximately 700 feet downstream of the River Road Bridge. There are many more meanders in M14-C with straightening occurring in 39 percent of its length, mostly in the upstream part of the segment. For 41 percent of the segment, River Road encroaches upon the western corridor, which has led to a human caused change in channel confinement, but did not change the broad valley type.

Erosion is present on both the east and west banks with 30 percent and 51 percent, respectively. Armoring in the form of rip-rap has been placed along 11 percent of the west bank and 5 percent of the east bank. Buffer widths are impacted in this segment from agricultural fields and the encroachment of River Road with about half of the west side having a buffer of less than 25 feet. The subdominant buffer width is 26 to 50 feet. Approximately ¼ of the east side has a buffer less than 25 percent, making it the subdominant buffer width. The dominant buffer width on this side is 26 to 50 feet. Land use within the riparian corridor consists of hay fields, residential homes and lawns, and roads. A stream side planting project in M14-B could be extended to Segment M14-C as part of a CREP project.

Deposition along Segment M14-C is much more pervasive than in other segments in M14 (Figure 7.19). This deposition has affected the reach enough to cause diagonal bars and steep riffles to form. There are also eight large point bars and four side bars. Channel planform has changed in M14-C as shown by the presence of an island, flood chute and a channel avulsion. Both the RGA and the RHA scored in the “fair” category. The RGA was fair as a result of major historic degradation, aggradation, widening, and planform adjustment. Numerous depositional features, exposed substrate,

Figure 7.19. Large point bars, bank erosion and lack of buffer in segment M14-C

unstable banks, lack of bank vegetation and riparian buffer, and channel straightening resulted in the decreased quality of habitat in segment M14-C.

Segment M14-D has experienced a stream type departure from its reference "C" to a stream type of "Bc" that is more entrenched and in stage II of the F channel evolution model. This segment is very incised (1.87 incision ratio) and has lost access to its historic floodplain. The length of M14-D is 590 feet and begins about 740 feet downstream of the River Road Bridge. River Road runs parallel to the Little River along the west side and has caused a change in confinement. The entire length of the segment has been straightened (Figure 7.20) and armored with rip-rap on the west bank, thereby increasing its stream power and degrading the channel bed. On the east bank, 40 percent of the bank has been armored with rip-rap. The rip-rap along the banks is preventing the stream from widening.

The entire length of the west side has a buffer width of less than 25 feet and the east side's buffer is 26 to 50 feet wide. Invasive vegetation is dominant on both stream banks and subdominant in both buffers. Dominant buffer vegetation on both sides is comprised of deciduous trees. The land use in the corridor is predominantly residential within both corridors.

The RGA was rated as "fair" for M14-D primarily due to extreme historic incision. Minor aggradation, widening, and planform adjustment are other processes identified in M14-D. Habitat condition is consistent with other segments in M14 rating as "fair". The "fair" condition was mostly from channel straightening and lack of riparian buffer, cover for fish, and substrates for epifaunal colonization.

Figure 7.20. Straightened section of segment M14-D

<u>Reach M15</u>
Streambank Plantings
Buffer Restoration
River Corridor Protection
Berm Removal
Dam Removal

Reach M15 was divided into four segments. The four segments vary in valley width, substrate size, and channel dimensions. The most downstream segment, M15-A, contains more depositional features and is a "Bc" type stream. M15-B is a bedrock gorge in the center of the reach. The narrow confinement in the bedrock gorge continues into M15-C making it an "F" type stream upstream of the gorge. Both M15-B and M15-C are "F" channels by reference. The last segment, M15-D, has a much wider valley than downstream and is a "C" channel.

M15-A is the most impacted segment within M15. The downstream end of Segment M15-A starts about 150 feet downstream of the River Road Bridge and continues for 2,326 feet until just after the western corridor becomes forested and the stream becomes a bedrock gorge. South Main Street and Palisades Road run parallel to the Little River for the entire segment length. These roads, along with driveways for industrial and commercial development on the western bank, have resulted in a significant human-caused change in channel confinement but no change in valley type from semi-confined. The channel is a "Bc" stream type in stage II of the F channel evolution model.

There is a bedrock grade control and an old dam (Figure 7.21) acting as a grade control in segment 15-A. The old dam is acting as a channel constriction and causing fine sediment to settle out upstream. The municipal sand storage is located on the western bank and there is significant bank erosion in the vicinity of this facility (Figure 7.22). A second parcel of land owned by the Town of Stowe, the wastewater treatment facility, abuts the northern bank of the Little River in segment M15-A and B.

Figure 7.21. Old dam grade control is constricting channel and causing sediment deposition upstream in M15-A.

Figure 7.22. Bank erosion and lack of woody vegetation in the vicinity of the municipal sand storage facility

There are several stormwater inputs including four road ditches and one field ditch. Most of Segment M15-A has been straightened and armored to protect development. Woody vegetation to help reduce bank erosion is lacking on both banks due to the presence of rip-rap and invasive bank vegetation. Buffers of less than 25 feet are present along the west bank (about 20 percent), but the dominant buffer width is 51 to 100 feet. The east side has a dominant buffer width of 26 to 50 feet. Residential is the dominant corridor land use on the east side, while industrial is dominant adjacent to the west bank.

The RGA scored in the "fair" category for M15-A. In response to major historic degradation, segment M15-A is now undergoing minor planform adjustment, aggradation and widening. The channel is responding to a major alteration of channel planform from channel straightening and the reduction in the width of the floodprone area from floodplain encroachments. The extensive rip-rap in the channel is preventing widening and planform adjustment. The RHA was rated as "fair". Fair fish cover, embeddedness, moderate sediment deposition, bank stability (west bank), riparian zones, and over 80 percent channel alteration are all contributing factors to the "fair" habitat conditions.

Segment M15-B is 559 feet long and is contained within a bedrock gorge (Figure 7.23). Due to the bedrock grade controls, Segment M15-B was not fully assessed. Since Segment M15-B is in a narrowly confined bedrock gorge with decent riparian buffers, it is presumed to be in reference condition. The western corridor is well forested, but the eastern corridor contains residential and commercial land use outside the valley wall.

Figure 7.23. Reference condition of bedrock gorge in Segment M15-B

Segment M15-C begins at the top of the bedrock and continues until the Route 108 bridge crossing. This segment is 717 feet in length. It has an "F" stream type due to its entrenchment. The channel has predominantly plane bed features, but there are some deep pools and riffle like characteristics. One hundred percent of M15-C has been straightened and there is old rip-rap along most of the east bank. Buffer widths were generally wider in M15-C than in M15-A, especially on the west side. The dominant buffer width on the west side is greater than 100 feet and 51 to 100 feet on the east side. The west corridor is primarily forested, while the dominant land use of the east corridor is commercial land.

Segment M15-C is the first segment on the Little River mainstem that is not incised. There has been some minor historic widening on the west bank due to the influence of rip-rap on the east bank. The RGA was scored as "good", but the RHA was scored in the higher end of "fair" due lack of slow velocity patterns, exposure of substrates in the channel, poor vegetative protection, and decreased riparian buffer on the east side.

Segment M15-D begins where the Route 108 Bridge crosses (Figure 7.24). The valley opens up and the channel is less entrenched making it a gravel dominated "C" stream in stage III of the F channel evolution model. The presence of three large point bars, one side bar, and one mid-channel bar indicates M15-D is more depositional than the downstream segments in M15 (Figure 7.25). The west side of the river has a buffer less than 25 feet along 80 percent of its length from the presence of mowed lawn for commercial purposes. Erosion is minimal to moderate due to the presence of rip-rap on both banks.

Figure 7.24. Route 108 bridge at downstream end of Segment M15-D

Figure 7.25. Large point bars within Segment M15-D

As in segments located downstream from the bedrock gorge, Segment M15-D has experienced major historic incision. The geomorphic processes that Segment M15-D is undergoing include minor aggradation, widening, and planform adjustment. Both the RGA and the RHA were rated in the higher end of the "fair" range. The "fair" rating for the RHA reflects the lack of vegetative protection on the banks from the rip-rap and presence of invasive vegetation, the riparian buffer condition and the embedded substrate (50-75%).

Little River Section C: Section C includes reaches M16 through M19, where the channel is moderately incised and the existing stream type is the same as the reference stream type. All reaches in this section are "C" channels that are in stage III of the F channel evolution model, i.e. they have incised, widened, and are generally undergoing major aggradation and planform change. A few reaches are also undergoing major widening. In general, the main difference between this 4.6 mile long section and section B is that section C is currently experiencing much greater aggradation and planform adjustment.

<u>Reach M16</u>
River Corridor Protection
Streambank Plantings
Buffer Restoration

Reach M16 was separated into three segments to capture the characteristics of a beaver dam influenced sub-reach, M16-B. Differences in substrate size and depositional features were also factors in segmenting the reach. All three segments have beaver dams (Figure 7.26), but M16-B is most affected by the beaver dams.

Figure 7.26. Beaver dam and deposition in M16-A

The confluence of the West Branch and the Little River is located just downstream of the start of M16-A. The segment continues about ¾ mile to just downstream of the Cemetery Road Bridge. Two properties owned by the Town of Stowe provide river frontage in segment M16-A. A 15.6 acre parcel off of Cemetery Road (Hayes land) abuts the Little River on the south side. The Hayes parcel is included in the Vermont Significant Wetland Inventory. A VAST trail goes through this property and is used for winter recreation (Tom Jackson, 2010 personal communication). The Mayo Farm, a 235 acre farm, is located on the north side of the river. The Stowe Land Trust holds a conservation easement on the Mayo Farm (Stowe Land Trust, 2008e).

The lower segment (M16-A) and the most upstream segment (M16-C) are much more depositional and have experienced more planform adjustment than the middle segment (Figures 7.26 and 7.27). Numerous point bars, mid-channel bars and side bars in M16-A and M16-C show that the stream is currently aggrading. The presence of flood chutes, channel avulsions and neck cutoffs are evidence of planform adjustment within Segments M16-A and M16-C. Both segments are sinuous "C" channels in stage III of the F channel evolution model.

The dominant buffer width on the east side is greater than 100 feet in segment M16-A, but almost half the west side's buffer is less than 25 feet in width. The dominant buffer width on the west side is 51-100 feet. The west corridor is primarily residential, while the east side has a dominant corridor land use of shrub/sapling. Both banks in M16-A are sandy banks with active erosion on about half their length, indicating that the channel is currently widening.

Figure 7.27. The large sand point bar reflects the major aggradation in M16-C.

Segment M16-A has undergone minor historic incision. The channel has an abandoned terrace and is developing a new floodplain. Active adjustment processes include major aggradation, widening and planform adjustment. The RGA and the RHA received a score of "fair" condition. Habitat scores for embeddedness, sediment deposition, bank stability, and riparian buffer zone (west side) reflect the deposition and widening that are occurring in M16-A.

M16-B has been heavily influenced by beaver dams (Figure 7.28). It starts just downstream of the Cemetery Road Bridge and continues upstream for 1,335 feet. The stream type is a gravel dominated "E" channel. Due to the presence of beaver dams, M16-B was not fully assessed. There is a short (about 300 feet) straightened and armored section associated with the Cemetery Road Bridge. The bridge is causing a channel and floodprone constriction.

Figure 7.28. Beaver dam influence in M16-B

Stream buffers are not as wide as in M16-A, with a 26-50 foot buffer dominant on the east side and 51-100 foot buffer dominant on the west side. About one third of both banks have buffer widths of less than 25 feet. Hay fields are dominant on the east corridor, while residential land use is dominant within the west corridor.

At the point where the beaver dam influence ends, M16-C begins and continues ¾ mile to 1,400 feet upstream of the West Hill Road Bridge. The buffers for M16-C are wider than the downstream segments. The dominant buffer width for both sides is greater than 100 feet and the subdominant is less than 25 feet. Within both east and west corridors, land use is predominantly shrub/sapling and subdominant is hay. Approximately 40 percent of each bank has experienced active erosion. There is some minor straightening and armoring associated with the bridge at West Hill Road. This bridge is constricting the channel and the floodplain and is responsible for some of the deposition in M16-C.

The channel adjustment processes in M16-C include: major historic incision, major aggradation and planform adjustment, and minor widening. As mentioned earlier, there are numerous depositional features and evidence of planform adjustment from an avulsion, neck cut off and flood chute. Like M16-A, the RGA and the RHA were scored in the "fair" category. Low habitat scores for sediment deposition, substrate cover, embeddedness, and bank stability indicate that the aggradation and widening in the segment is negatively affecting the habitat.

<u>Reach M17</u>
River Corridor Protection

Reach M17 is about ½ mile long and very similar to segments M16-A and M16-C in that it is an incised depositional reach which has abandoned its old floodplain and is creating a new one. Gravel is the dominant substrate in this "C" channel, which is also in stage III of the F channel evolution model.

The dominant buffer in M17 is greater than 100 feet and the subdominant buffer is 51-100 feet for both sides. The dominant land use for both corridors is shrub/sapling. There is one beaver dam on the downstream end of M17 and numerous depositional features including large point bars at every bend. Both banks are sandy non-cohesive banks and are experiencing moderate to high erosion, especially on outside bends (Figure 7.29).

Figure 7.29. Bank erosion and point bar in M17

The channel adjustment processes within M17 are major historic incision, major aggradation and planform change, and minor widening. There are no flood chutes, but on the downstream end there is a channel avulsion indicating major planform adjustment. The RGA rated as "fair", and the RHA rated in the lower end of the "good" category. The parameters most impacting the habitat condition are sediment deposition and bank stability.

Reach M18
Buffer Restoration
River Corridor Protection
Bridge Replacement

A change in planform resulted in three segments within reach M18. A straightened section of 514 feet was separated out as the middle segment (M18-B), while the rest of the reach upstream was not straightened. More planform adjustment was observed in the lowest and uppermost segments than in the middle segment. All segments are borderline "C" channels with width to depth ratios just under 12. As with downstream reaches, M18 has historically incised, is very depositional and experiencing planform adjustment. There has been a human caused change in valley confinement in only one segment (M18-B) from Little River Farm Road, but it is minor and has not changed the valley type.

Riparian buffers were predominantly greater than 100 feet in all three segments except for the east side of M18-A, which is 51-100 predominantly. In M18-A, the corridor to the west is primarily forested providing good riparian protection, while the eastern corridor is shrub/sapling. The corridors within M18-B are predominately forested and shrub/sapling for the east and west side, respectively, while both sides contain residential land use as subdominant. Shrub/sapling is the dominant land use within both corridors in segment M18-C. All three segments had RGA and RHA scores of "fair".

The lower segment, M18-A, begins about ½ mile downstream of the Little River Farm Road crossing and is 2,350 feet in length. The segment is currently undergoing major aggradation (Figure 7.30), major planform adjustment with minor widening. Planform adjustment was evident from the two avulsions which have cut off meander bends to form new channels.

Figure 7.30. A large unvegetated gravel bar showing the major aggradation in M18-A.

Figure 7.31. Straightened section of M18-B

Located downstream of the Little River Farm Road Bridge, segment M18-B is 514 feet in length and has been extensively straightened (Figure 7.31). Segment M18-B contains a diagonal bar and steep riffle, indicating that the segment is aggrading. However, aggradation, widening, and planform adjustment are minor adjustment processes for Segment M18-B.

Segment M18-C begins just upstream of Littler River Farm Road and continues for ¾ mile until the confluence with Moss Glen Brook (T8.01). The major adjustment processes for segment M18-C includes all four processes: degradation, aggradation, widening, and planform change. M18-C was the only segment in M18 with major widening, which was evident from the bank erosion along approximately 30 percent of both banks.

Reach M19
Streambank Plantings
Buffer Restoration
River Corridor Protection
CREP
Berm Removal

Reach M19 was divided into two segments due to changes in valley width and incision. The downstream segment (M19-A) is more incised than the upstream segment (M-19-B). The upstream valley is wider than downstream, although both segments still have very broad valleys. Both segments are gravel dominated "C" riffle-pool channels in stage F-III of channel evolution. M19 is very depositional with twenty steep riffles and numerous bars. (Figure 7.32).

Segment M19-A begins at the confluence of Moss Glen Brook (T8.01) and continues for 1,044 feet until the valley becomes much wider. The dominant buffer in M19-A is greater than 100 feet and on the west side there are no buffers less than 25 feet. On the eastern side, buffers less than 25 feet in width make up about ¼ of the length. Land use within the river corridor in M19-A is predominantly shrub/sapling and subdominant is pasture and hay.

The top part of M19-B begins about 500 feet downstream of the Moulton Lane crossing and flows for another mile through a forested section and then into a more agricultural area. In M19-B, buffer width is predominantly 26-50 on the east side and 51-100 feet on the west side. Buffer widths less than 25 feet in M19-B encompass approximately 30 percent of the east side and 10 percent of the west side, respectively. The nearby farm and adjacent hay fields make the middle to lower part of this segment an ideal CREP project location.

The percentage by length of erosion is greater in Segment M19-A indicating more widening than in Segment M19-B, although some of the outside bends in M19-B are eroding. Segment M19-B also has rip-rap armoring on its banks especially in the vicinity of Tansy Hill Road Bridge (Figure 7.33), while downstream there is none. This bridge is causing a channel and floodprone constriction. Just upstream of Tansy Hill Road Bridge, there is evidence of gravel mining. Dominant land use in M19-B is hay within the eastern corridor and forested in the western corridor.

Both segments have historically incised, but as mentioned before, M19-A is slightly more incised than M19-B. M19-A is currently undergoing major widening, while it is minor in M19-B. Both segments resulted in "fair" RGA scores and RHA scores in the higher end of the "fair" range. RHA scores were lower in Segment M19-A than M19-B primarily due to more bank erosion and poor fish cover and substrate for epifaunal colonization.

Figure 7.32. Large point bar in M19-A

Figure 7.33. Rip-rap along bank upstream of Tansy Hill Road Bridge in M19-B

Little River Section D: Section D is the most upstream section and includes reaches M20 and M21. This section, which is about 1.4 miles, is not incised and deposition is the dominant process, putting these reaches in stage IIc of the D channel evolution model. The main difference between Section D and Section C (downstream) is the lack of incision. The upper 1,050 feet of this Section D is a bedrock gorge and was, therefore, not fully assessed.

Reach M20
Buffer Restoration
River Corridor Protection
Berm Removal

Reach M20 begins approximately 500 feet downstream of the bridge at Moulton Lane crossing and continues ¾ mile to upstream of the Sterling Valley Road crossing. This reach has good floodplain access except for some areas where the access is poor due to streamside berms. One of these berms is just upstream of Moulton Lane Bridge and is associated with a large pond within the river corridor. Straightening has occurred along one-third of the reach due to association with the two bridges, which are both floodprone constrictions, but not channel constrictions. There are three areas that

Figure 7.34. Severe erosion and lack of riparian buffer along east bank in Reach M20

were identified earlier by LCPC as places where dredging has occurred. This reach contains four beaver dams, which have made parts of the channel very deep.

The dominant buffer category is greater than 100 feet on both banks, but there are some areas where the buffer is less than 25 feet. Some of these areas with limited buffer are experiencing major erosion within the vicinity of crop fields (Figure 7.34). Forest is the dominant land use within the corridor in this reach, but the subdominant is crop in the eastern corridor and residential in the western corridor.

The channel adjustment processes for M20 include: major aggradation, major planform adjustment, and minor widening. Aggradation is very evident in this reach with many depositional features including five diagonal bars and ten steep riffles. The width to depth ratio was difficult to measure in wider areas due to the presence of the diagonal bars. Planform adjustment was observed through four flood chutes and two islands. The RGA was scored on the higher end of “fair”, while the RHA came out as “good”. The only parameter that was rated in the fair category was channel alteration.

Reach M21
River Corridor Protection
Berm Removal

Reach M21 needed to be broken up into two segments due to the channel becoming a bedrock gorge in the upper 1,050 feet. Segment M21-A begins 400 feet upstream of the Sterling Valley Road crossing and continues 2,174 feet until the stream becomes a bedrock gorge. This segment has been historically straightened in the vicinity of roads and adjacent to agricultural lands. There is a relatively good buffer in some areas with a dominant buffer of greater than 100 feet, but a subdominant buffer of 26-50 feet on both sides with some areas less than 25 feet. Sterling Valley Road runs parallel to M21-A along the west bank and encroaches on the corridor for approximately 1,200 feet. There are berms associated with the road, totaling 470 feet in length along the segment.

Segment M21-A has not incised and therefore follows the D channel evolution model. With the presence of steep riffles and diagonal bars among other depositional features (Figure 7.35), this reach is currently undergoing major aggradation. The combination of channel alteration and sediment deposition has resulted in major planform adjustment. Minor widening is occurring from the moderate to high erosion on both banks.

Figure 7.35. Steep riffle and point bar within Segment M21-A.

Similar to Reach M20, the RGA scored "fair" for M21-A and the RHA scored "good". Except for bank stability and channel alteration, habitat parameters were scored either in good or reference categories.

Miller Brook

Miller Brook is one of the major tributaries to the Little River. Five reaches of Miller Brook were assessed. All reaches were moderately or severely incised, with two reaches (the second most downstream and the most upstream) having stream type departures. The reference stream type for all reaches is "C". With the exception of the most upstream reach (T4.05), the Miller Brook reaches are all stage III of the F channel evolution model. T4.05 has not yet widened and is in stage F-II.

Reach T4.01
Berm Removal
Bridge Replacement

Reach T4.01 begins at the confluence with the Little River, which is about 900 feet downstream of the Moscow Road Bridge, and continues for about ½ mile along Nebraska Valley Road. Of all the reaches in the study, T4.01 had the highest width to depth ratio indicating it has become extremely wide.

Figure 7.36. Lack of buffer along western bank causing bank failure in Reach T4.01

The Little River corridor is encroached by Nebraska Valley Road along the west side for approximately 2,100 feet. From the encroachment of the road, there is a human caused change in valley width, but not a change in valley type. Along the east side of the corridor in the upper part of T4.01, there is a 7 foot high berm that is about 115 feet long. Approximately ¼ of the length of reach T4.01 has been historically straightened for the road and has a buffer less than 25 feet on the western bank. The lack of buffer has led to bank erosion mostly on the western bank with bank failures and a mass failure occurring on the upstream end of the reach (Figures 7.36 and 7.37). A second mass failure was observed on the downstream end of the reach on the eastern bank (Figure 7.38).

Along the western side of T4.01, the dominant buffer is 51-100 feet and the subdominant is 26-50 feet. The eastern side contains a higher quality buffer with a dominant width of greater than 100 feet and subdominant of less than 25 feet. Forested land on the east side provides good river corridor habitat. However, the western side is predominantly residential land with hay as the subdominant land use.

Figure 7.37. Mass failure 12 feet high along western bank in Reach T4.01

Figure 7.38. Mass failure 20 feet high along eastern bank in Reach T4.01

The alteration of the corridor on the western side and the straightening of the channel have resulted in channel incision and then widening to extreme levels (50.4 width to depth ratio). Reach T4.01 is also experiencing major aggradation (Figure 7.39) and planform adjustment. The RGA scored in “fair” condition. Deposition within riffle areas has created many steep riffles and diagonal bars. Other depositional features include many side bars and four mid-channel bars. Planform adjustment is evident from one island and frequent flood chutes. The RHA scored in the low end of the “good” range.

Figure 7.39. Major aggradation shown by very large side bar in Reach T4.01

<u>Reach T4.02</u>
Buffer Restoration
Berm Removal
Bridge Replacement

Reach T4.02 is a 1.5 mile long reach with a high width to depth ratio (30.5) and is very depositional. The incision ratio is 2.0; indicating Miller Brook has poor floodplain access. Signs of incision were also observed from the presence of rejuvenating tributaries. The incision has led to the channel becoming more entrenched causing a stream type departure from a “C” channel to an “F” channel. The Nebraska Valley Road Bridge is out of alignment with the stream channel and is causing a channel and floodprone constriction (Figure 7.40). There has been a human caused change in valley width due to the placement of Nebraska Valley Road within the valley of the eastern side.

Straightening has occurred along approximately 20 percent of the reach and T4.02 has lost access to its floodplain from the placement of a 330 foot berm along the west bank near the downstream end. Other than the berm, the western corridor is generally in good condition with a dominant buffer width of greater than 100 feet and a subdominant width of 51-100 feet. The eastern corridor has been encroached upon with development for approximately 12 percent of the reach length. The dominant buffer width for the eastern side is greater than 100 feet with a subdominant width of 26-50 feet. Land use is predominantly forest on both sides with residential subdominant on both sides. Although deciduous trees are the dominant vegetation on the banks, invasive plants, such as Japanese knotweed, are subdominant.

Reach T4.02 has experienced extreme historic incision, major aggradation and planform adjustment, and minor widening. Numerous steep rifles, diagonal bars, side bars, point bars and mid-channel bars indicate that some sediment is working its way down Miller Brook is getting deposited here (Figure 7.41). Many islands and flood chutes were observed indicating major planform adjustment. The RGA and the RHA were scored as “fair”. The “fair” RHA rating was the result of numerous depositional features and the presence of invasive vegetation on the banks.

Figure 7.40. Bridge crossing of Nebraska Valley Road constricting Reach T4.02

Figure 7.41. Island with diagonal bar and steep riffle along Reach T4.02

<u>Reaches T4.03</u>
River Corridor Protection
Bridge Replacement

Reach T4.03 was broken into two segments due to differences in valley width, planform and slope, and depositional features. The stream type for both segments T4.03-A and T4.03-B is a cobble dominated “Cb” channel (Figure 7.42). Both segments are in stage III of the F channel evolution model. T4.03 is located along Nebraska Valley Road, which encroaches on the river corridor. Straightening has occurred on approximately ¼ and ½ of the length of segments T4.03-A and T4.03-B, respectively, with windrowing having also taken place in segment T4.03-A.

Because of Nebraska Valley Road, the western buffer is much more impacted than the eastern buffer in Reach T4.03. The eastern side of both segments has a forested buffer greater than 100 feet. The subdominant buffer on the eastern side of T4.03-A is 51-100 feet. On the western side of Segment T4.03-A, the buffer is predominantly greater than

100 feet and less than 25 feet subdominant. The dominant buffer on the western side in T4.03-B is 26-50 feet with 51-100 feet subdominant. The two segments have good dominant bank and buffer vegetation, except for T4.03-A which has predominantly invasive species, such as Japanese knotweed, within the buffer and on the banks.

Segments T4.03-A and T4.03-B have historically incised, with greater incision in T4.03-B. Geomorphic processes in T4.03-A include minor historic incision and widening, major aggradation, and major planform adjustment. T4.03-B shows major historic incision and aggradation, while widening and planform adjustment are minor. Aggradation was evident from many steep riffles and diagonal bars along with other depositional features (Figure 7.43). The RGAs for both segments in T4.03 were scored in the "fair" category. The RHA was scored "fair" for T4.03-A and "good" for T4.03-B. In general, the RHA scored lower for T4.03-A primarily due to banks vegetated with invasive species, bank erosion, and lack of substrates for fish cover and epifaunal colonization.

Figure 7.42. Cobble dominated "Cb" channel in Reach T4.03

Figure 7.43. Steep riffle and mid-channel bar showing major aggradation in Segment T4.03-A

<u>Reach T4.04</u>
River Corridor Protection
Berm Removal

Reach T4.04 begins just upstream of the confluence with an unnamed tributary (T4.03S1) and continues for about ¾ mile along Nebraska Valley Road. The stream type for T4.04 is a gravel dominated "Cb" channel. The channel is in stage III of the F evolution model. Approximately 20 percent of Reach T4.04 has been historically straightened.

In T4.04, 70 percent of the buffer is less than 25 feet making it the dominant buffer width on the west side, while the subdominant width is 51-100 feet. The east side has a dominant buffer width greater than 100 feet and forest is the dominant land use. The west side has a dominant land use of residential due to the encroachment of Nebraska Valley Road.

Major historic incision and planform adjustment are evident in T4.04 by the presence of rejuvenating tributaries (Figure 7.44), four flood chutes, six islands (Figure 7.45), and one channel avulsion. Widening and aggradation are minor in T4.04. The RGA scored “fair”. Reach T4.04 has a diversity of velocity/depth patterns and stable banks. The habitat condition came out as “good”.

Figure 7.44. Rejuvenating tributary in Reach T4.04

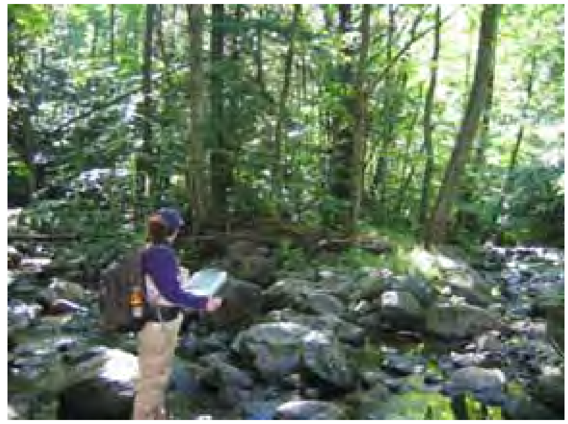

Figure 7.45. One of many islands showing major planform adjustment in Reach T4.04

<u>Reach T4.05</u>
River Corridor Protection
Berm Removal
Dam Removal
Bridge Replacement

Reach T4.05 is 1,925 feet long and is very well forested along both banks. The reach begins at the confluence with an unnamed tributary (T4.04S1) and continues upstream to the dam at Lake Mansfield. Although T4.05 is well forested and has wide buffers, it has been impacted by the dam at Lake Mansfield (Figure 7.46). The dam has caused the reach to be sediment starved and to incise to an extreme degree (incision ratio of 2.0). The extreme historic incision has led to a stream type departure from a cobble dominated “C” channel to a cobble dominated “Bc” channel. The stage of channel evolution is F-II, which indicates that the stream has lost access to its floodplain and has become more entrenched.

Figure 7.46. Lake Mansfield Trout Club dam at upstream end of T4.05

Figure 7.47. Constricting bridge at Nebraska Valley Road in Reach T4.05

Nebraska Valley Road encroaches upon the eastern corridor for 360 feet at the upstream end. The buffers for this reach are very well forested with a dominant width of greater than 100 feet and subdominant 51-100 feet just at the upstream end where Nebraska Valley Road encroaches upon the corridor. Large trees along the banks are holding soil in place, thereby resulting in little bank erosion. The dominant land use within both corridors is forest. The subdominant corridor land use is residential due to the road. Nebraska Valley road crosses Miller Brook again with a bridge that is constricting both the channel and the floodplain (Figure 7.47).

Similar to reach T4.04, T4.05 has many depositional features as well as features indicating planform adjustment. Tributary rejuvenation was also observed in T4.05. Although there has been extreme historic incision; aggradation, widening, and planform adjustment are still minor processes. The RGA was scored as "fair" mainly due to the extreme incision. Because of wide and well vegetated buffers and banks, the RHA was scored in the high end of the "good" range. Reach T4.05 is a good candidate for river corridor protection due to its high quality river corridor. The only parameter that was scored low in the RHA was substrate exposure at riffles due to the presence of some depositional features.

Gold Brook

Gold Brook is a major tributary to the Little River. Seven reaches were assessed during Phase 2. The assessed reaches are very variable in terms of stream type, degree of incision and channel evolution stage, but in general most reaches have minor aggradation, widening, and planform adjustment currently occurring.

Reach T6.01
Streambank Plantings
Berm Removal
Bridge Replacement

Reach T6.01 is 2,235 feet long and begins at the confluence with the Little River. It follows along Gold Brook Campground on its southern bank and hayfields on its northern bank to upstream of the crossing at Waterbury Road (VT 100). The channel is a gravel dominated "C" stream type with major historic incision in stage F-III of the channel evolution model.

Approximately 70 percent of Reach T6.01 has been heavily bermed and about one-third has been armored with rip-rap and hard bank on the southern bank (Figure 7.48). Due to the armoring, there is little bank erosion on the southern bank. However, there is bank erosion along one-third of the northern bank. Roads and development encroach upon the corridor for approximately 60 percent of the channel length. Straightening has occurred along 80 percent of the reach. Gold Brook has also been dredged from its mouth up to VT 100. There is a bridge at the crossing at VT 100 causing both a channel and a floodprone constriction. The upstream part of this reach has a higher slope than near the mouth and includes a bedrock grade control (Figure 7.49).

Figure 7.48. Rip-rap along southern bank in Reach T6.01

Figure 7.49. Bedrock grade control in upper part of Reach T6.01

Buffers in T6.01 are predominantly less than 25 percent on both banks. The subdominant buffer width is 26-50 feet for both sides. Dominant land use is residential in the southern corridor and hay in the northern corridor.

The widespread alteration of this channel has caused major historic incision as well as current major planform change. Widening is currently a minor process within the reach due to the presence of rip-rap on the southern bank. Although there was one steep riffle and diagonal bar, aggradation is still a minor process in T6.01. As a result of the deviation from natural conditions of the corridor and channel, T6.01 rated as “fair” for both the RGA and RHA. The extensive channel straightening, lack of riparian buffers, and reduced vegetative protection on the west bank are the major factors that have led to the “fair” RHA score.

<u>Reaches T6.02</u>
River Corridor Protection

Reach T6.02 starts upstream of VT 100 and continues for about ½ mile. Reach T6.02 is a “B” type step-pool stream with no historic incision. There are many bedrock grade controls throughout Reach T6.02, thereby preventing downcutting of the bed (Figure 7.50). The bedrock in T6.02 is also causing channel constriction in four locations.

Figure 7.50. Bedrock grade control in Reach T6.02 preventing incision in this segment

Gold Brook Road runs along approximately 70 percent of the ½ mile length of Reach T6.02, but the road is outside the valley wall. Reach T6.02 is semi-confined and has not been impacted by changes in valley width from human influences. Except for in a few locations where Gold Brook Road is within the valley wall, T6.02 has well vegetated buffers and banks.

The only major geomorphic process in Reach T6.02 is aggradation. The channel evolution stage is IIb of the D model, which signifies that the reach has not incised and the dominant active adjustment process is aggradation. Widening and planform change are minor active adjustment processes. The RGA and RHA for T6.02 were rated “good”. No habitat parameters scored in the fair or poor categories.

Reach T6.03
Berm Removal

Reach T6.03 was divided into four segments due to differences in channel dimensions, planform and slope, corridor encroachment, valley width, and to capture a subreach with a different reference stream type of “C” (T6.03-C). Except for one segment (T6.03-B), all of the segments in Reach T6.03 have not incised or are slightly incised.

Segment T6.03-A is one-quarter mile long and begins where the southern side has road encroachment, buffers less than 25 feet, and is straightened and armored. The bedrock grade control in T6.03-A is preventing incision in this segment (Figure 7.51).

Figure 7.51. Bedrock grade control in Segment T6.03-A

Segment T6.03-B, which is 536 feet long, is almost entirely straightened and rip-rapped on the southern bank with a buffer of less than 25 feet due to Gold Brook Road (Figure 7.52). Gold Brook begins to go away from the road at the start of T6.03-C, which is approximately ¼ mile long. The buffers on T6.03-C are well forested and predominantly greater than 100 feet except for a short distance on the southern bank from encroaching development and roads. The corridor in Segment T6.03-D becomes heavily impacted again on the southern side from the encroachment of Gold Brook Road, rip-rap, straightening, and reduced buffer width. The dominant buffer on the southern side is 51-100 feet and subdominant is 26-50 feet. Dominant land use is forest on the northern side and residential on the southern side due to the road.

Segments T6.03-A and T6.03-D are “B” streams that are in stage I of the F channel evolution model, i.e. they have not incised and the sediment transport capacity is in equilibrium with its sediment load. The only minor active process in these segments is widening. For Segment T6.03-B, the scenario is very different. Segment T6.03-B stands out from the other Gold Brook segments/reaches. Extensive channel alteration in T6.03 has led to extreme historic incision (ratio of 2.85) and a stream type departure from a "B" to an "Fb" stream type. The active processes in T6.03-B are minor aggradation, widening, and planform adjustment. This segment is in stage II of the F model.

A subreach with a different reference stream type than the rest of the segments in T6.03 was captured in T6.03-C. Segment T6.03-C is predominantly a "C" stream with a slope more like a "B" stream. It has only slightly incised and is currently undergoing extreme aggradation (Figure 7.53). Therefore, the evolution stage of D-IId was assigned. Channelization in the upstream segment (T6.03-D) and the drop in slope and change in entrenchment in T6.03-C are the major causes of aggradation within this subreach. Historic incision, widening and planform adjustment are minor processes in T6.03-C.

Figure 7.52. Rip-rap armoring, lack of buffer, and stormwater input in Segment T6.03-B

Figure 7.53. Major aggradation in Segment T6.03-C

The RGA was rated "fair" in segments T6.03-B and T6.03-C and "good" in segments T6.03-A and T6.03-D. The extreme incision in T6.03-B contributed to the "fair" geomorphic condition and in T6.03-C, the extreme aggradation resulted in the "fair" rating. Segment T6.03-B was the only segment in Reach T6.03 with a "fair" score for the RHA. The rest of the segments had ratings of "good" for the RHA. Segment T6.03-B was rated as fair due to its heavily altered channel and lack of bank vegetative cover and riparian buffer on the southern side.

Reaches T6.04
River Corridor Protection
Berm Removal

Reach T6.04 begins where the channel becomes incised again about 200 feet upstream of the covered bridge at the confluence of an unnamed tributary, T6.03S1. The reach continues 1,065 feet until just upstream of the next unnamed tributary, T6.04S1.
There has been a human caused change in valley width due to Stowe Hollow Road, but the valley width was not altered enough to change the valley type. The buffers in Reach T6.04

are wide and well vegetated with the dominant buffer width for both sides greater than 100 feet.

There are two berms within the river corridor preventing the stream from accessing its floodplain. On the southern bank of T6.04 there is a 150 foot berm constructed with fill preventing floodplain access (Figure 7.54) and another 100 foot berm upstream.

An incised tributary was observed in T6.04 indicating major historic incision. Reach T6.04 is a "Cb" channel in stage III of the F channel evolution model. Active geomorphic processes include minor aggradation, widening, and planform adjustment.

Figure 7.54. Berm with fill preventing floodplain access in Reach T6.04

The RGA was rated as "fair" and the RHA was rated in the lower end of "good". Major historic channel incision mostly contributed to the "fair" RGA score. Channel alteration from berms and armoring and reduced riparian buffer on the south side resulted in the low "good" score for the RHA.

<u>Reach T6.05</u>
River Corridor Protection
Streambank Plantings
Culvert Replacement
Bridge Replacement

Reach T6.05 begins just downstream of the Stowe Hollow Road crossing and continues for approximately another ¾ mile until ¼ mile upstream of the Upper Hollow Road crossing. T6.05 is 35 percent straightened (Figure 7.55) and has had a human caused change in valley width due to Stowe Hollow Road and North Hollow Road. These roads encroach upon the corridor for approximately ½ of the channel length.

The dominant buffer width on the northern side of T6.05 is 51-100 feet and on the southern side is greater than 100 feet. The subdominant buffer width on both sides is less than 25 feet, with 50 percent of its length on the northern side within 25 feet of land cover other than riparian vegetation. There are three stream crossings in reach T6.05, two of which are constricting the channel.

An incised tributary was observed in T6.04 and T6.05 (Figure 7.56), but historic incision is still minor due to a moderate incision ratio (1.39). Although all other geomorphic processes are minor in T6.05, the RGA still scored as "fair". The RHA scored in the "good" range with channel straightening the only parameter with a fair score.

Figure 7.55. Straightened section of Reach T6.05

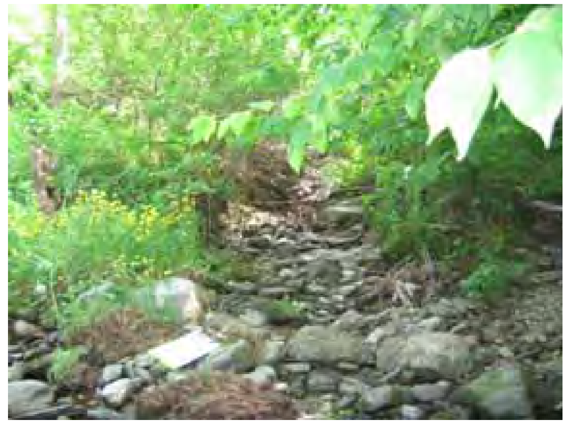

Figure 7.56. A rejuvenating tributary indicates that T6.05 has incised

Reach T6.06
River Corridor Protection
Culvert Replacement
Berm Removal

Reach T6.06 was divided into two segments (T6.06-A and T6.06-B) due to variable channel dimensions and reference stream types. The first segment, T6.06-A (Figure 7.57), begins just upstream of the Upper Hollow Road crossing and continues about ½ mile until the Bryan Road crossing. T6.06-B, continues for 1,555 feet until just downstream of the crossing at North Hollow Road.

There has been a human caused change in valley width in both segments due to North Hollow Road. Approximately ½ of T6.06-A is straightened with possible windrowing, but T6.06-B is not straightened. Except for areas where development and North Hollow Road encroaches the corridor, the buffers are wide and well vegetated. Berms are located in both segments totaling approximately 600 feet. There are also several grade controls and bedrock constrictions (Figure 7.58).

Figure 7.57. Typical channel in Segment T6.06-A

Figure 7.58. Bedrock grade control and channel constriction in T6.06-B

Segment T6.06-A is a cobble dominated "Cb" stream in stage III of the F channel evolution model, while T6.06-B is a "Ba" stream in stage F-II, indicating that it is more entrenched and has not yet widened. In Segment T6.06-A historic incision is minor with an incision ratio of 1.36. Historic incision is greater in T6.06-B (ratio of 1.76) and is therefore a major process. Aggradation and widening are minor in both segments, while planform adjustment is major due to the presence of islands, flood chutes, and a recent channel avulsion (Figure 7.59). The change in channel planform resulted in a "fair" RGA score for T6.06-A. Historic incision and planform adjustment contributed to the "fair" RGA score in T6.06-B.

Figure 7.59. Outlet of channel avulsion in Segment T6.06-A

The RHA scored "good" for T6.06-A with channel straightening, a reduced riparian buffer on the south side, and sediment deposition causing embedded substrate impacting the RHA score. In Segment T6.06-B, the only parameter noted as fair was sediment deposition causing increased embeddedness in the channel.

<u>Reach T6.07</u>
River Corridor Protection
Culvert Replacement
Berm Removal
Dam Removal

Reach, T6.07 begins about 250 feet downstream of the North Hollow Road crossing and continues in between North Hollow Road and Putnam Forest Road for about another ½ mile. There has been a human caused change in valley width due to North Hollow Road and Putnam Forest Road, which encroach approximately 60 percent of the reach by length. Channel straightening has occurred along about ½ of T6.07. There are many bedrock constrictions and grade controls including an old rock dam at the downstream end which is a fish passage issue and has caused significant scour just downstream (Figure 7.60). Two mass failures within T6.07 are providing a sediment source for the channel (Figure 7.61).

Compared to other reaches in Gold Brook, T6.07 has been severely incised (ratio of 2.41) and the stream type has departed from a "Ba" stream to a "Fa" stream in stage F-II. The severe historic incision is a result of the extensive channel straightening and alterations associated with the old dam.

Other geomorphic adjustment processes in Reach T6.07 are currently minor, but the RGA was scored "fair" due to the extreme historic incision and stream type departure. The RHA resulted in a score at the low end of the "good" range. Channel straightening and the riparian buffer width on the south side contributed to the RHA score as did depositional features and increased substrate embeddedness.

Figure 7.60. Old rock dam grade control in T6.07

Figure 7.61. Mass failure in T6.07

Moss Glen Brook

Moss Glen Brook is a major tributary that enters the Little River just downstream of the beginning of reach M19, where the Little River becomes Sterling Brook. This confluence is located just downstream of where Stagecoach Road crosses Moss Glen Brook. The three most downstream reaches on Moss Glen Brook were assessed for Phase 2 (T8.01, T8.02 and T8.03). In general, these reaches are very depositional, have been historically incised and in some cases their channels are over wide. All reaches are gravel dominated “C” channels by reference, but the upper portion of the assessed reaches have experienced stream types departures due to extreme historic channel incision.

<u>Reach T8.01</u>
Streambank Plantings
Buffer Restoration
CREP
Culvert Replacement

Reach T8.01 was divided into two segments due to channel dimensions. The upper segment is 950 feet in length, while the lower segment is about ¾ mile in length. The bankfull width in the upstream segment (T8.01-B) is much wider than the downstream segment (T8.01-A). Both segments T8.01-A and T8.01-B are rather sinuous and flow through a very broad agricultural valley.

Channel straightening has occurred extensively in both segments, and bank erosion is moderate to high. The extensive erosion in Segment T8.01-B indicates that the channel is currently widening (Figure 7.62). Rip-rap armoring is most pervasive on the northern banks with approximately 20 percent in both segments. Other impacts include a mass failure at the upstream end of T8.01-B (Figure 7.63) providing sediment and causing increased deposition downstream. There is also a beaver dam in the center of T8.01-A causing deposition (Figure 7.64).

Figure 7.2 Over widened channel in cross section of T8.01-B

Figure 7.63. Mass failure acting as a major sediment source in Moss Glen Brook in T8.01-B

Buffers in both segments are lacking vegetation with the dominant buffer width on both sides of T8.01-A as 26-50 feet and the subdominant width less than 25 feet. The dominant buffer width in T8.01-B is less than 25 feet on both sides that covers the entire length of the segment. The dominant buffer vegetation on both sides of this segment is herbaceous indicating a lack of quality riparian vegetation. Land use within both corridors of T8.01-A is predominantly crop land with residential land subdominant. On the southern side of T8.01-B, bare land is the dominant land use with pasture subdominant. Pasture is dominant in the northern corridor in segment T8.01-B. This would be a good location for a CREP project due to the lack of buffer and proximity to cow pastures (Figure 7.65). Another impact present in both segments includes dredging. There is a channel avulsion in Segment T8.01-A which may have been caused by channel dredging.

Figure 7.64. Beaver dam causing deposition in T8.01-A

Figure 7.65. Lack of buffer and severe bank erosion in cow pasture area in T8.01-B

Segments T8.01-A and T8.01-B are similar in terms of their buffer and bank conditions, but they differ in channel morphology. Both segments are "C" channels that have major historic incision, but the width to depth ratio in T8.01-B is much higher (39.5). This high width to depth ratio, as well as the large amount of bank erosion, indicates the channel is currently undergoing major widening. Segment T8.01-A is in stage III of the F channel evolution model and segment T8.01-B is in stage IV. The presence of many depositional features including mid-channel, point, side, and diagonal bars and steep riffles shows that segment T8.01-A is currently undergoing major aggradation. Riffles are sedimented and diagonal. Aggradation is minor for T8.01- B and planform adjustment is minor for both segments.

The RHA and RGA scored as "fair" for both segments. The "fair" RGA score in T8.01-A was in response to the major historic incision and major active aggradation, while in T8.01-B, it was mostly due to major historic incision and widening. Reduced fish cover and epifaunal substrate, depositional features, channel straightening unstable banks on the south side and lack of vegetation in the riparian buffer have impacted the habitat in T8.01-A. The extensive straightening and extreme lack of buffer vegetation in T8.01-B contributed to the "fair" habitat condition. Depositional features, exposed substrate, unstable banks on the north side, and a lack of vegetation on both banks has contributed to the "fair" condition.

<u>Reach T8.02</u>
Streambank Plantings
Buffer Restoration
River Corridor Protection
CREP

Reach T8.02 was divided into two segments based on differences in channel dimensions. The downstream segment is 2,107 feet long and begins upstream of the Pucker Street Bridge. Channel characteristics in this segment are very similar to T8.01-B. The cross section in this segment revealed that the width to depth ratio was very high (43.1) indicating major widening. Segment T8.02-B begins where the channel width becomes narrower and continues for 1,763 feet until just upstream of an unnamed tributary (T8.02S2). The stream channel in T8.02-B is much narrower than T8.02-A and is severely incised. The extreme incision has led to a stream type departure from a "C" to an "F" stream.

The southern buffer is forested in T8.02 with the dominant buffer width of greater than 100 feet in both segments. On the northern side however, the buffer width is less than 25 feet in half of SegmentT8.02-A. The dominant buffer width on the northern side of Segment T8.02-B is 26-50 feet. Land use within the southern corridor is predominantly forest in both segments. The northern corridor is mostly crop land in T8.02-A and pasture in T8.02-B. Both segments have been impacted by extensive channel straightening. The entire length of T8.02-B has been straightened (Figure 7.66) and over half of T8.02-A has been straightened.

Segment T8.02-A is an interesting segment in that it is the only segment/reach in Moss Glen Brook that did not show any evidence of historic incision. However, all other geomorphic processes are actively occurring and major. The segment probably incised a long time ago, which led to the widening, aggradation and planform change but it is no longer incising. Similar to T8.01-B, T8.02-A is a "C" type stream in stage IV of the F channel evolution model. The extensive straightening in Segment T8.02-B led to severe historic incision (ratio of 2.79) resulting in a stream type departure from a "C" to an "F". Segment T8.02-B is in stage F-III. Current geomorphic processes include minor aggradation, widening and planform adjustment.

Both the RGA and the RHA were scored as fair in both segments. The RGA was "fair" in T8.02-A due to major aggradation, widening and planform change. In Segment T8.02-B, the RGA was "fair" mostly due to the extreme incision. Extensive channel straightening, depositional features, lack of riparian buffer, and reduced vegetative cover on the northern bank contributed to a "fair" RHA score in T8.02-A. Unstable banks, extreme channelization, and lack of riparian buffer on the northern bank are the main causes for reduced habitat quality in T8.02-B.

Figure 7.66. Straightened section of segment T8.02-B

Reach T8.03
Buffer Restoration
CREP

Reach T8.03 is approximately 1,500 feet long and begins just upstream of an unnamed tributary (T8.02S2). Channel characteristics in this reach are very similar to T8.02-B. Severe incision has led to a stream type departure from a "C" to an "F" stream.

Buffer conditions are similar to downstream in that the southern buffer is very forested and greater than 100 feet. On the northern side, the dominant buffer width is 26-50 feet, and the subdominant width is less than 25 feet (Figure 7.67). Dominant land use in the southern corridor is forest and in the northern corridor is crop. Reach T8.03 has been extensively straightened which has led to extreme incision (2.3 incision ratio). Erosion is moderate to high in this reach indicating major widening (Figure 7.68).

Figure 7.67. Lack of buffer in Reach T8.03

Figure 7.68. Bank erosion on northern bank in Reach T8.03

The extensive straightening in T8.03 has led to a chain of events beginning with extreme historic incision which then resulted in major aggradation, major widening, and minor planform adjustment. Numerous depositional features were noted during the phase 2 assessment, including steep riffles and diagonal bars. The RGA resulted in "fair". The RHA was scored in the low "good" range with depositional features, extensive channelization, unstable banks and lack of buffer on the northern side causing lower RHA scores. Habitat diversity and well vegetated banks and buffers on the southern side contributed to the "good" condition.

7.3 Site Level Opportunities

Site specific projects were identified using the criteria outlined by the VANR in Chapter 6 – Preliminary Identification and Prioritization (Vermont Agency of Natural Resources 2007a). This planning guide is intended to aid in the development of projects that protect and restore river equilibrium. Project maps (Figure 7.68 through Figure 7.72) and tables (Table 6 through 10) have been developed for the Lower Little River (reaches M06 through M14), the Upper Little River (reaches M15 through M21), Miller Brook, Gold Brook and Moss Glen Brook. The tables provide information for each project, including the project strategy, technical feasibility, priority and general cost. A total of 51 projects were identified to promote the restoration or protection of channel stability and aquatic habitat in the Little River watershed. The projects are broken down by category as follows: 4 conservation (river corridor protection alone), 15 passive restoration (river corridor protection, streamside plantings and buffer improvement projects); 31 active restoration (12 bridge or culvert replacement or retrofit projects, and 16 berm and 4 dam removal projects).

High priority projects include river corridor protection to provide attenuation of sediment and floodwaters through conservation and corridor easements, riparian buffer improvement areas, and the replacement or retrofitting of undersized stream crossing structures. Information from the Phase 2 stream geomorphic assessment and VANR bridge and culvert assessment could be used to inform the Town of Stowe of which stream crossings are contributing to localized instability. The high priority projects include:

Lower Little River (see Figure 7.68 and Table 6)
- **Active Restoration** by removing Moscow Mills Dam (project #3);
- **Passive Restoration** of river corridor and streamside plantings from the confluence with Gold Brook to just downstream of River Road crossing (project #5).

Upper Little River (see Figure 7.69 and Table 7)

- **Active Restoration** by removing Pike Dam (project #1);
- **Active Restoration** by removing berm near Municipal Storage Facility (project #2);
- **Passive Restoration** of river corridor and riparian buffer from Mountain Road to Cemetery Road (project #3);
- **Conservation** of river corridor from above Cemetery Road to end of reach M17 (project #4);
- **Passive Restoration** of river corridor and riparian buffer from Little River Farm Road to about 1,200 feet more downstream (project #5);
- **Conservation** of river corridor from Little River Farm Road to confluence with Moss Glen Brook (project #7);
- **Passive Restoration** of river corridor and streamside plantings from just upstream of Moss Glen Brook to just below Tansy Hill Road (project #8);
- **Active Restoration** by removing berms near Tansy Hill Road crossing (project #9);
- **Active Restoration** by removing berms near Moulton Lane crossing (project #11);
- **Active Restoration** by removing berms located upstream of Sterling Valley Road (project #12);

Miller Brook (see Figure 7.70 and Table 8)

- **Active Restoration** by removing berm located about 600 feet downstream of first Nebraska Valley Road crossing (project #4);
- **Passive Restoration** of river corridor and riparian buffer from Nebraska Valley Road to 1,050 feet downstream of tributary confluence (project #6);
- **Conservation** of river corridor from unnamed tributary to Miller Brook to across from intersection of Old Country Road and Nebraska Valley Road (project #9);
- **Active Restoration** by removing the berm near Nebraska Valley Road crossing (project #10);
- **Active Restoration** by removing dam at Lake Mansfield (project #11);

Gold Brook (see Figure 7.71 and Table 9)

- **Active Restoration** by removing berm along Gold Brook Campground (project #1);
- **Passive Restoration** with streamside plantings from confluence of Little River and Gold Brook to Route 100 (project #3);
- **Active Restoration** by removing berm located approximately ½ mile upstream of Gold Brook Road crossing along Gold Brook Road (project #4);
- **Active Restoration** by removing berm just upstream of unnamed tributary to Gold Brook (project #6);
- **Conservation** of river corridor from about 450 feet upstream of Waterbury Road crossing to just downstream of Stowe Hollow Road crossing(project #7);
- **Active Restoration** by replacing undersized culvert that is causing localized geomorphic instability (project #8).
- **Conservation** of river corridor from forested area to ½ mile upstream of intersection of North Hollow Road and Putnam Forest Road (project #12);
- **Active Restoration** by removing berms in the vicinity of North Hollow Road (project #14);
- **Active Restoration** by removing berms upstream of Bryan Road (project #15);
- **Active Restoration** by removing dam just downstream of North Hollow Road crossing (project #18);

Moss Glen Brook (see Figure 7.72 and Table 10)

- **Active Restoration** by replacing double undersized culvert at Stagecoach Road that is causing localized geomorphic instability (project #1).
- **Passive Restoration** of river corridor and streamside plantings from confluence with Little River and upstream about 1,200 feet (project #2);
- **Passive Restoration** of river corridor and streamside plantings from Pucker Street to forested area (project #3);
- **Passive Restoration** of river corridor and riparian buffer adjacent to Pucker Street (project #4).

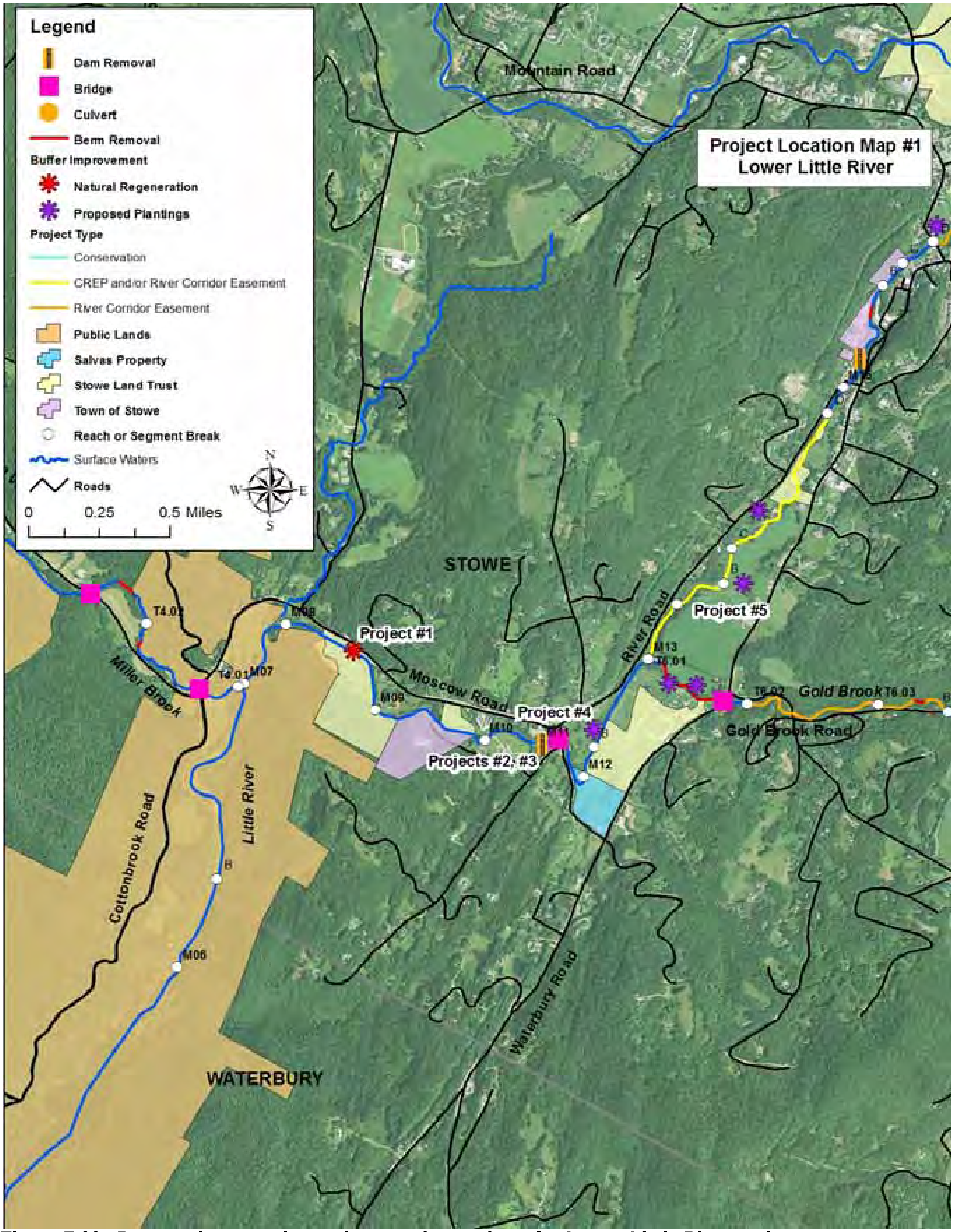

Figure 7.68. Proposed restoration and protection projects for Lower Little River mainstem

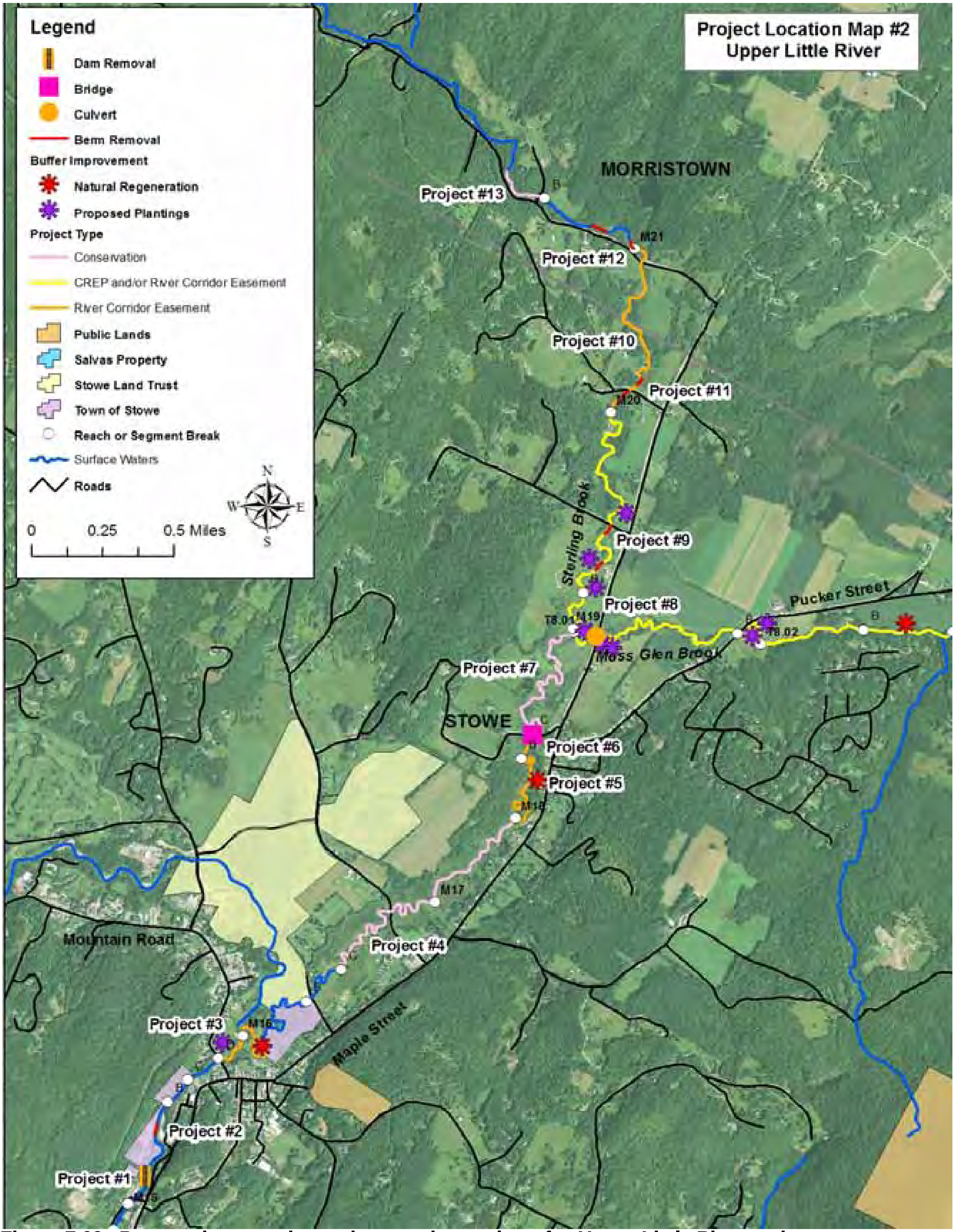

Figure 7.69. Proposed restoration and protection projects for Upper Little River mainstem

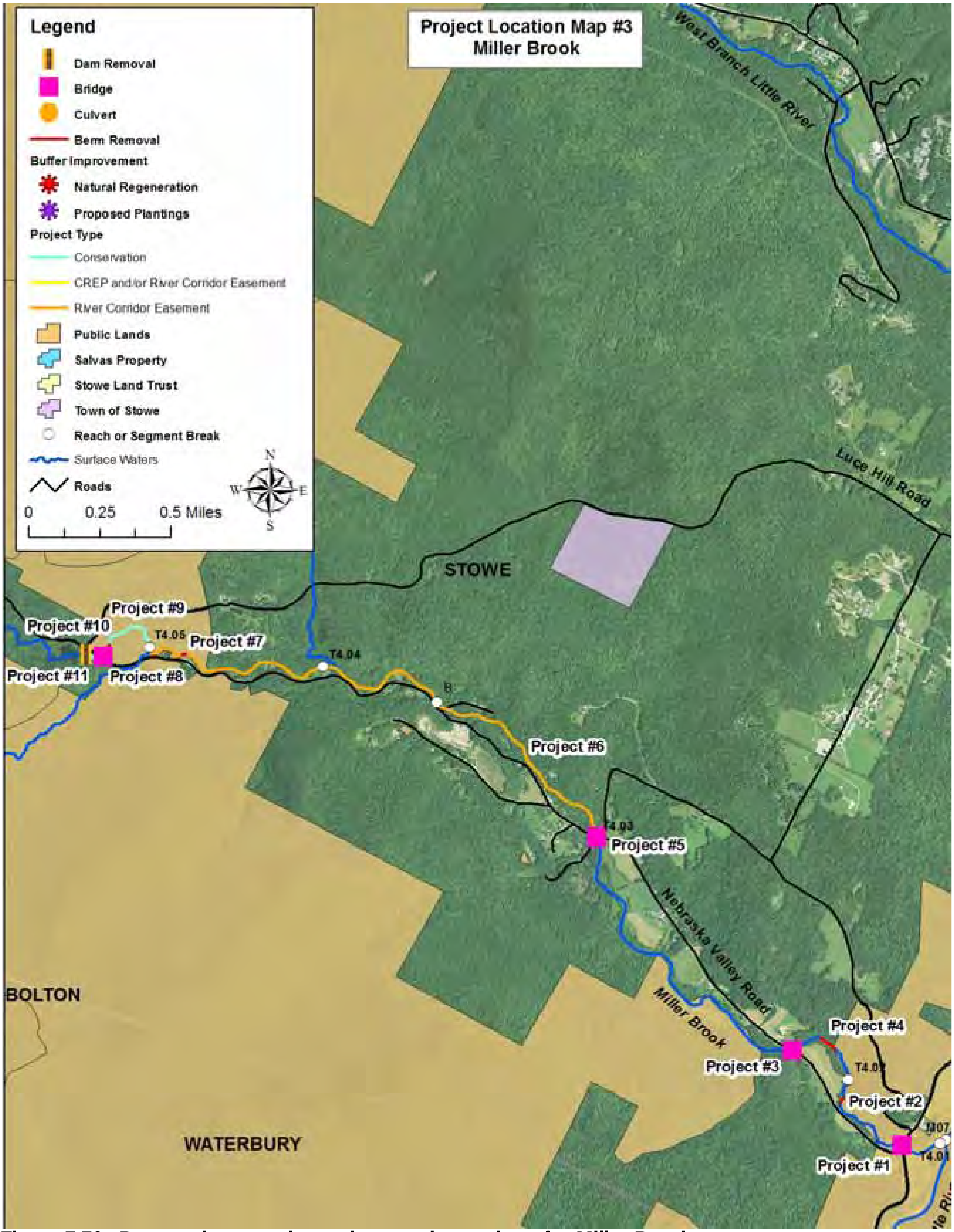

Figure 7.70. Proposed restoration and protection projects for Miller Brook

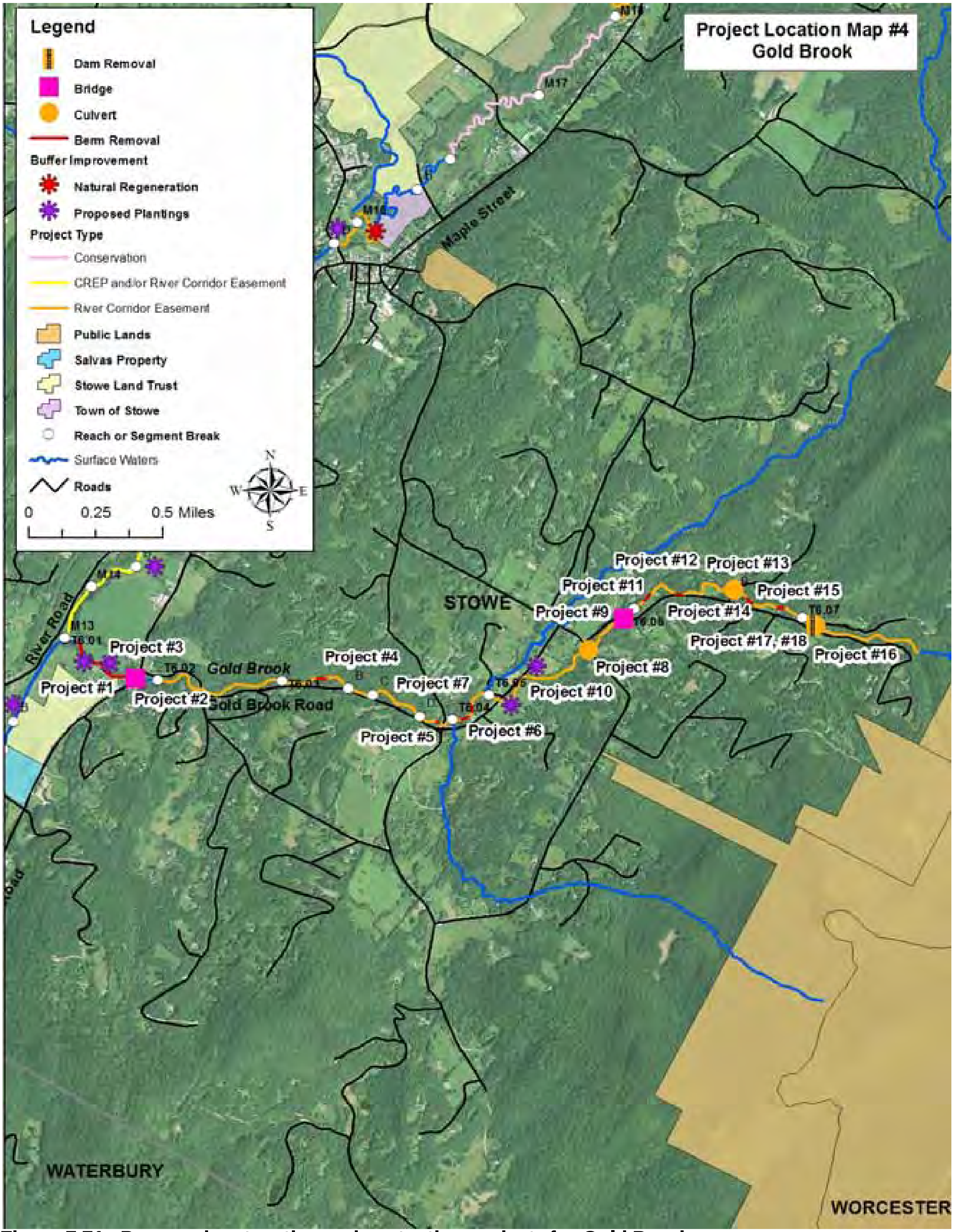

Figure 7.71. Proposed restoration and protection projects for Gold Brook

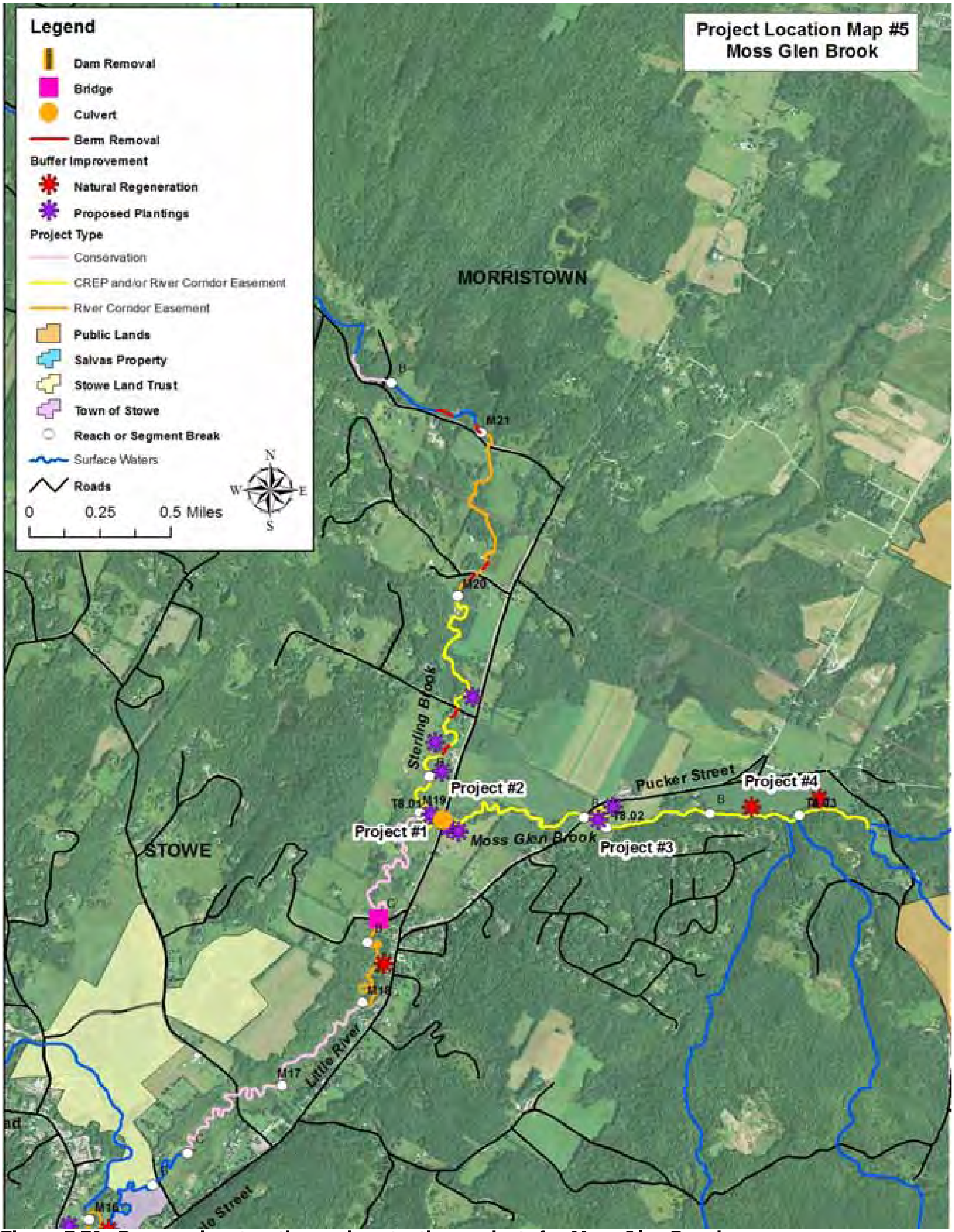

Figure 7.72. Proposed restoration and protection projects for Moss Glen Brook

**Table 6. Lower Little River Site Level Opportunities for Restoration and Protection
Stowe, Vermont**

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Land Use Conversion	Potential Partners
#1 From Barrows Brook confluence to old mill location off of Moscow Road. M08 and M09	Passive Restoration	The proximity of Moscow Road impedes a potential buffer improvement project in places. M08 and M09 are natural attenuation reaches. According to Tom Jackman, a knotweed eradication project is being considered for the Dumont parcel.	Buffer restoration – Natural Regeneration: Increase buffer width along hay field to extent feasible with low cost plantings or let vegetation grow back on its own.	Low priority	Improve water quality	Low cost	Hay fields and residential lawns to forested buffer	VANR, LCPC, landowner
#2 Moscow Road crossing M11	Active Restoration	The Moscow Road bridge was found to be partially compatible using the geomorphic screening tool. Scour and alignment are issues with the bridge.	Bridge Replacement	Moderate priority	Improved geomorphic stability	High cost for replacement	Unknown	Town of Stowe, VANR, LCPC
#3 At downstream end of M11 about 300 feet downstream of Moscow Road crossing M11	Active Restoration	Moscow Mills Dam is about 20 feet high and is a fish passage issue. Downstream corridor for reach M10 is well developed. Channel downstream is channelized and well armored.	Alternative analysis for dam removal	High priority due to fish passage issue and sediment retention. Dam is located on bedrock.	Improve habitat and geomorphic stability	Cost of alternative analysis and dam destruction	Dam to natural stream channel	VANR, LCPC, Town of Stowe

Table 6. Lower Little River Site Level Opportunities for Restoration and Protection
Stowe, Vermont

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Land Use Conversion	Potential Partners
#4 From downstream end of Gold Brook Campground to confluence with Gold Book. M12-A and M12-B	Passive Restoration	Reaches are straightened; poor buffers due to campground and residential areas.	Streamside plantings	Moderate priority for plantings due to minor widening and planform adjustment	Prevent erosion, improve habitat and reduce water temperature	Loss of campground sites for owner; Low cost for plantings	Commercial to forest.	VANR, LCPC, landowners
#5 From Gold Brook confluence to just downstream of River Road crossing. M13 and M14	Passive Restoration	Bank erosion and lack of buffer along residential land, agricultural fields and road. River Road impedes buffer improvement in many places. Very depositional and major planform change.	Protect River Corridor through corridor easement and/or CREP; Improve riparian buffer. Streamside plantings.	High priority for conservation easement; high priority for plantings. Planting will allow connectivity to adjacent forested areas.	Flood and sediment attenuation; Prevent erosion, improve habitat and reduce water temperature	Cost of corridor easements. Low cost of plantings.	Agricultural and residential land to forested	VANR, LCPC, landowners, CREP, land trust

Table 7. Upper Little River Site Level Opportunities for Restoration and Protection Stowe, Vermont

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Land Use Conversion	Potential Partners
#1 Pike dam located about 550 feet upstream of River Road crossing M15-A	Active Restoration	Pike dam with 20 foot drop is a fish passage issue. Abutments are causing a channel constriction and deposition and scour. The dam is breached.	Alternative analysis for dam removal	High priority	Improve habitat and geomorphic stability	Cost of alternative analysis and dam destruction	Dammed stream to natural stream channel	VANR, LCPC, Town of Stowe
#2 Near the Municipal Storage Facility M15-A	Active Restoration	A 215 foot long berm was observed during the Phase 1 windshield survey in the vicinity of the Municipal Storage Facility in Stowe. The berm was not marked during Phase2 and should therefore be field verified.	Alternative analysis for berm removal.	High priority. Berm currently not vegetated.	Improve habitat and geomorphic stability	Cost of alternatives analysis for berm removal, excavation, and planting	Berm to floodplain	Town of Stowe, VANR, LCPC
#3 From Mountain Road to above Cemetery Road M15- D and M16-A	Passive Restoration	Commercial and residential land uses lacking riparian vegetation; extensive erosion in M16-A	Protect River Corridor through corridor easement; Buffer restoration – Natural Regeneration: Increase buffer width where feasible with low cost plantings or let vegetation grow back on its own. Streamside plantings in M15-D.	High priority for corridor easement; High priority for plantings in M15-D and buffer restoration. Buffer restoration will allow connectivity to adjacent forested areas.	Flood and sediment attenuation; Improve water quality.	Cost of corridor easements; Low cost for buffer improvement.	Commercial and residential land to forested	VANR, LCPC, landowners, land trust

Table 7. Upper Little River Site Level Opportunities for Restoration and Protection
Stowe, Vermont

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Land Use Conversion	Potential Partners
#4 About 700 feet above Cemetery Road to west of Pucker Street near intersection of Westview Heights Drive M16-C and M17	Conservation	Well forested buffers. Abundant erosion on both banks. Very sinuous.	Protect River Corridor through corridor easement.	High priority for corridor easement	Flood and sediment attenuation.	Cost of conservation easement	No new structures in corridor	VANR, LCPC, landowners, land trust
#5 From Little River Farm Road to about 1,200 feet more downstream M18-A and M18-B	Passive Restoration	Forested corridor, but areas with no buffer. Also no buffer near crossing. Straightened section with recent channel avulsion.	Protect River Corridor through corridor easement; Buffer restoration – Natural Regeneration: Increase buffer width where feasible with low cost plantings or let vegetation grow back on its own.	High priority for corridor easement	Flood and sediment attenuation. Improve water quality.	Cost of corridor easements. Low cost of plantings.	Herbaceous to forested	VANR, LCPC, landowners, land trust
#6 Little River Farm Road crossing M18-B	Active Restoration	The Little River Farm Road bridge was found to be partially compatible using the geomorphic screening tool. There is scour above and rip-rap within the structure.	Bridge Replacement	Moderate priority	Improved geomorphic stability	High cost for replacement	Unknown	Town of Stowe, VANR, LCPC

Table 7. Upper Little River Site Level Opportunities for Restoration and Protection Stowe, Vermont								
Project # Segment	**Type of Project**	**Site Description Including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility and Priority**	**Other Social Benefits**	**Costs**	**Land Use Conversion**	**Potential Partners**
# 7 From Little River Farm Road to confluence with Moss Glen Brook M18-C	Conservation	Very sinuous and extensive active planform adjustment. River needs room to reach its equilibrium stage.	Protect River Corridor	High priority for conservation easement.	Flood and sediment attenuation	Cost of conservation easement	No new structures in corridor	VANR, LCPC, landowners, land trust
#8 From 800 feet upstream of Moss Glen Brook and continue along Stagecoach Road upstream to just downstream of Tansy Hill Road M19-A and M19-B	Passive Restoration	Agricultural and residential land uses; segment is in currently widening and aggrading and will continue to adjust its planform.	Protect river corridor through corridor easement and/or CREP; Improve riparian buffer. Streamside plantings.	High priority for corridor easement; high priority for plantings. In active erosion areas plant trees away from bank.	Flood and sediment attenuation. Prevent erosion, improve habitat and reduce water temperature	Cost of corridor easement; low cost for plantings	Agricultural and residential to forested	VANR, LCPC, landowners, CREP, land trust
#9 Downstream from Tansy Hill Road crossing. M19-B	Active Restoration	One 225 foot long berm was observed just downstream of Tansy Hill Road crossing and another ~200 foot berm was observed near the farm on the east bank during the Phase 1 windshield survey. This berm should be field verified.	Alternative analysis for berm removal. Berm just downstream of Tansy Hill Road may be protecting adjacent pond.	High priority	Improve habitat and geomorphic stability	Cost of alternatives analysis for berm removal, excavation, and planting	Berm to floodplain	VANR, LCPC, landowners

**Table 7. Upper Little River Site Level Opportunities for Restoration and Protection
Stowe, Vermont**

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Land Use Conversion	Potential Partners
#10 From just downstream of Moulton Lane crossing to Sterling Valley Road crossing M20	Passive Restoration	Modified channel on downstream end with mostly forested land but pockets of crop and residential also. Buffers could be improved in some locations. Beaver dam influence in one spot.	Protect River Corridor through conservation easement; Buffer restoration – Natural Regeneration: Increase buffer width to extent feasible with low cost plantings or let vegetation grow back on its own. Establish no mow zones.	Low priority for planting anything due to beaver activity	Flood and sediment attenuation. Improved water quality	Low cost	Agricultural land to forested	VANR, LCPC, landowners, land trust
#11 Just downstream of Moulton Lane crossing to upstream end of Pond on east side above Moulton Lane M20	Active Restoration	One 160 foot long berm to protect a nearby man made pond was observed just upstream of Moulton Lane crossing and another 140 foot berm was observed just downstream of the crossing.	Alternative analysis for berm removal	High priority	Improve habitat and geomorphic stability	Cost of alternatives analysis for berm removal, excavation, and planting	Berm to floodplain	VANR, LCPC, landowners
#12 Upstream of Sterling Valley Road Crossing M21-A	Active Restoration	One 180 foot long berm was observed at downstream end of segment and another 300 foot berm was observed just before stream gets very close to Sterling Valley Road – both on south bank facing downstream.	Alternative analysis for berm removal	High priority	Improve habitat and geomorphic stability	Cost of alternatives analysis for berm removal, excavation, and planting	Berm to floodplain	VANR, LCPC, landowners

Table 7. Upper Little River Site Level Opportunities for Restoration and Protection Stowe, Vermont

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Land Use Conversion	Potential Partners
#13 From just downstream of Dr. Neel Road crossing to about 1000 feet upstream M21-B	Conservation	Well forested bedrock gorge	Protect River Corridor through corridor easement	Low priority for corridor easement due to bedrock control	Scenic location for recreation; preserve forested buffer for cool water temperatures for fish and other aquatic organisms	Cost of conservation easement	No new structures in corridor	VANR, LCPC, landowners, land trust

Table 8. Miller Brook Site Level Opportunities for Restoration and Protection Stowe, Vermont

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Land Use Conversion	Potential Partners
#1 Moscow Road crossing T4.01	Active Restoration	The Moscow Road bridge is undersized and was found to be partially compatible using the geomorphic screening tool. Deposition and scour are issue with the bridge.	Bridge Replacement	Moderate priority	Improved geomorphic stability	High cost for replacement	Unknown	Town of Stowe, VANR, LCPC
#2 Along island bank just upstream of where Nebraska Valley Road is near stream T4.01	Active Restoration	A 130 foot long, 7 foot high berm was observed at upstream end of reach along an island.	Alternative analysis for berm removal.	Low priority: well vegetated with trees	Improve habitat and geomorphic stability	Cost of alternatives analysis for berm removal, excavation, and planting	Berm to floodplain	VANR, LCPC, landowners

Table 8. Miller Brook Site Level Opportunities for Restoration and Protection
Stowe, Vermont

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Land Use Conversion	Potential Partners
#3 Nebraska Valley Road crossing T4.02	Active Restoration	The Nebraska Valley Road bridge is undersized and was found to be partially compatible using the geomorphic screening tool. Deposition, scour and alignment are issue with the bridge. The bridge is in poor condition.	Bridge Replacement	Moderate priority	Improved geomorphic stability	High cost for replacement	Unknown	Town of Stowe, VANR, LCPC
#4 Downstream of Nebraska Valley Road crossing T4.02	Active Restoration	A 330 foot long berm was observed near downstream end of reach.	Alternative analysis for berm removal.	High priority	Improve habitat and geomorphic stability	Cost of alternatives analysis for berm removal, excavation, and planting	Berm to floodplain	VANR, LCPC, landowners
#5 Nebraska Valley Road crossing T4.03-A	Active Restoration	The Nebraska Valley Road bridge is undersized and was found to be partially compatible using the geomorphic screening tool. Deposition, scour and alignment are issue with the bridge.	Bridge Replacement	Moderate priority	Improved geomorphic stability	High cost for replacement	Unknown	Town of Stowe, VANR, LCPC

Table 8. Miller Brook Site Level Opportunities for Restoration and Protection Stowe, Vermont								
Project # Segment	**Type of Project**	**Site Description Including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility and Priority**	**Other Social Benefits**	**Costs**	**Land Use Conversion**	**Potential Partners**
#6 Nebraska Valley Road bridge to 1,050 downstream of confluence with unnamed tributary T4.04S1 T4.03-A, T3.03-B, and T4.04	Passive Restoration	Well forested on eastern bank, but western bank is encroached by Nebraska Valley Road and therefore buffer improvement and easement in those spots are not possible.	Protect River Corridor through corridor easement.	High priority for corridor easement due to major planform adjustments and aggradation.	Flood and sediment attenuation. Improve water quality.	Cost of conservation easement	No new structures in corridor	VANR, LCPC, landowners, land trust
#7 About 600 feet downstream of confluence with unnamed tributary T4.04	Active Restoration	An 80 foot long berm was observed during the Phase 1 windshield survey. The presence of this berm should be field verified.	Alternative analysis for berm removal.	Low priority	Improve habitat and geomorphic stability	Cost of alternatives analysis for berm removal, excavation, and planting	Berm to floodplain	VANR, LCPC, landowners
#8 Nebraska Valley Road crossing T4.05	Active Restoration	The Nebraska Valley Road bridge is undersized and was found to be partially compatible using the geomorphic screening tool. Deposition and scour are issue with the bridge.	Bridge Replacement	Moderate priority	Improved geomorphic stability	High cost for replacement	Unknown	Town of Stowe, VANR, LCPC

**Table 8. Miller Brook Site Level Opportunities for Restoration and Protection
Stowe, Vermont**

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Land Use Conversion	Potential Partners
#9 From unnamed tributary confluence to just across from intersection of Old Country Road and Nebraska Valley Road T4.05	Conservation	Well forested corridors except for upstream section with one crossing and road encroachment. Upstream dam makes conserving this reach more crucial.	Protect River Corridor through corridor easement.	High priority for corridor easement.	Flood and sediment attenuation	Cost of conservation easement	No new structures in corridor	VANR, LCPC, landowners, land trust
#10 In vicinity of Nebraska Valley Road crossing T4.05	Active Restoration	Two berms were observed in this reach both nearby the bridge at Nebraska Valley road. One is about 160 feet long on the north bank near the bridge and the other is about 150 long just downstream from the bridge on the right bank.	Alternative analysis for berm removal.	High priority	Improve habitat and geomorphic stability	Cost of alternatives analysis for berm removal, excavation, and planting	Berm to floodplain	VANR, LCPC, landowners
#11 At Lake Mansfield at intersection of Nebraska Valley Road and Old Country Road T4.05	Active Restoration	Extremely incised downstream of dam (ratio of 2.0), which has led to stream type departure. Corridor is well forested downstream, which has helped other processes to remain minor.	Alternative analysis for dam removal	High priority but low feasibility due to managed lake for game fishing by Lake Mansfield Trout Club	Improve habitat and geomorphic stability	Cost of alternative analysis and dam destruction	Dammed lake to stream channel	VANR, LCPC, Lake Mansfield Trout Club

Table 9. Gold Brook Site Level Opportunities for Restoration and Protection Stowe, Vermont								
Project # Segment	**Type of Project**	**Site Description Including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility and Priority**	**Other Social Benefits**	**Costs**	**Land Use Conversion**	**Potential Partners**
#1 Just upstream of confluence with Little River to Route 100 T6.01	Active Restoration	Campground within one corridor and agricultural in the other. Berm lines entire south bank between Route 100 and the Little River.	Alternative analysis for berm removal.	High priority; maybe low feasibility due to current land use.	Improve habitat and geomorphic stability	Cost of alternatives analysis for berm removal, excavation, and planting	Berm to floodplain	Gold Brook Campground, VANR, LCPC
#2 Waterbury Road crossing T6.01	Active Restoration	The Waterbury Road bridge is partially compatible using the geomorphic screening tool. Deposition below is an issue with this bridge.	Bridge Replacement	Moderate priority	Improved geomorphic stability	High cost for replacement	Unknown	Town of Stowe, VANR, LCPC
#3 Just upstream of confluence with Little River to Route 100 T6.01	Passive Restoration	Lack of adequate buffer on both sides due to agricultural fields and campground road.	Streamside plantings.	High Priority for stream plantings	Prevent erosion, improve habitat and reduce water temperature	Low cost for plantings	Agricultural and commercial to forested	VANR, LCPC, landowners
#4 Approximately 1/2 mile upstream of Gold Brook crossing along Gold Brook Road T6.03-A	Active Restoration	A 180 foot long berm between Gold Brook and Gold Brook Road.	Alternative analysis for berm removal.	High priority	Improve habitat and geomorphic stability	Cost of alternatives analysis for berm removal, excavation, and planting	Berm to floodplain	VANR, LCPC. landowners

Table 9. Gold Brook Site Level Opportunities for Restoration and Protection Stowe, Vermont								
Project # Segment	**Type of Project**	**Site Description Including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility and Priority**	**Other Social Benefits**	**Costs**	**Land Use Conversion**	**Potential Partners**
#5 Just downstream of Stowe Hollow Road crossing T6.03-D	Active Restoration	A 50 foot long rock berm between Gold Brook and Gold Brook Road.	Alternative analysis for berm removal.	Low priority due to short length	Improve habitat and geomorphic stability	Cost of alternatives analysis for berm removal, excavation, and planting	Berm to floodplain	VANR, LCPC. landowners
#6 Just upstream of unnamed tributary confluence on east bank. T6.04	Active Restoration	A 150 foot long berm of cobble and gravel fill between Gold Brook and Stowe Hollow Road behind house and a 100 foot long fill berm upstream. Buffer less than 25 feet on south bank near the berms.	Alternative analysis for berm removal. Streamside plantings.	High priority	Improve habitat and geomorphic stability. Prevent erosion, improve habitat and reduce water temperature	Cost of alternatives analysis for berm removal, excavation, and planting	Berm to floodplain. Residential to forest.	VANR, LCPC. landowners
#7 From about 450 feet upstream of Waterbury Road crossing to just downstream of Stowe Hollow Road T6.02, T6.03, T6.04	Passive Restoration	Except for road encroachment in T6.02 and T6.03 and some development in T6.04, well forested corridors.	Protect River Corridor through corridor easement.	High priority for corridor easement.	Improve sediment transport	Cost of conservation easement	No new structures in corridor	VANR, LCPC, landowners, land trust

Table 9. Gold Brook Site Level Opportunities for Restoration and Protection Stowe, Vermont

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Land Use Conversion	Potential Partners
#8 Upper Hollow Road crossing T6.05	Active Restoration	The Upper Hollow Road culvert is undersized. It was found to be fully compatible using the geomorphic screening tool, but it is an aquatic organism passage issue. Deposition and scour are also issues with the culvert.	Culvert Replacement	High priority	Improved geomorphic stability	Moderate cost for replacement	Unknown	Town of Stowe, VANR, LCPC
#9 North Hollow Road crossing T6.05	Active Restoration	The North Hollow Road bridge is undersized and mostly incompatible using the geomorphic screening tool. Deposition and scour are also issues with the bridge.	Bridge Replacement	Moderate priority	Improved geomorphic stability	High cost for replacement	Unknown	Town of Stowe, VANR, LCPC
#10 From Stowe Hollow Road crossing upstream about 1,250 feet along no buffer areas. T6.05	Passive Restoration	Lack of adequate buffer on both sides.	Protect river corridor through corridor easement; Streamside plantings.	Moderate Priority due to moderate incision	Prevent erosion, improve habitat and reduce water temperature	Low cost for plantings	Agricultural to forested	VANR, LCPC, landowners, land trust

Table 9. Gold Brook Site Level Opportunities for Restoration and Protection
Stowe, Vermont

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Land Use Conversion	Potential Partners
#11 At the North Hollow Road crossing in Gold Brook. T6.05	Active Restoration	A 60 foot long berm between Gold Brook and North Hollow Road on right bank.	Alternative analysis for berm removal.	Low priority due to short length of berm	Improve habitat and geomorphic stability	Cost of alternatives analysis for berm removal, excavation, and planting	Berm to floodplain.	VANR, LCPC. landowners
#12 From forested area to ½ mile upstream of intersection of North Hollow Road and Putnam Forest Road T6.06, and T6.07	Passive Restoration	Except for stream crossings, some development and road encroachments, corridors are well forested.	Protect River Corridor through corridor easement.	High priority for corridor easement.	Flood and sediment attenuation and improve sediment transport in T6.07	Cost of conservation easement	No new structures in corridor	VANR, LCPC, landowners, land trust
#13 Bryan Road crossing T6.06-A	Active Restoration	Bryan Road culvert is very undersized and mostly compatible using the geomorphic screening tool. Deposition, scour, and a steep riffle are also issues with the culvert.	Culvert Replacement	Moderate priority	Improved geomorphic stability	Moderate cost for replacement	Unknown	Town of Stowe, VANR, LCPC

Table 9. Gold Brook Site Level Opportunities for Restoration and Protection Stowe, Vermont

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Land Use Conversion	Potential Partners
#14 About 580 feet upstream of North Hollow Road crossing and also upstream of where stream gets very close to the road T6.06-A	Active Restoration	A 120 foot long berm on north bank and a 50 foot berm on south bank near residence on North Hollow Road. Another 130 foot berm is on south bank right where stream abuts the road. Possible windrowing on both berms.	Alternative analysis for berm removal.	High priority	Improve habitat and geomorphic stability	Cost of alternatives analysis for berm removal, excavation, and planting	Berm to floodplain.	VANR, LCPC. landowners
#15 Upstream of Bryan Road crossing T6.06-B	Active Restoration	A 150 foot long berm upstream of Bryan Road and then another berm about 120 feet long approximately 550 feet more upstream.	Alternative analysis for berm removal.	High priority	Improve habitat and geomorphic stability	Cost of alternatives analysis for berm removal, excavation, and planting	Berm to floodplain.	VANR, LCPC. landowners
#16 North Hollow Road crossing T6.07	Active Restoration	The North Hollow Road culvert is very undersized and mostly compatible using the geomorphic screening tool. Deposition and scour are also issues with the culvert.	Culvert Replacement	Moderate priority	Improved geomorphic stability	Moderate cost for replacement	Unknown	Town of Stowe, VANR, LCPC

Table 9. Gold Brook Site Level Opportunities for Restoration and Protection Stowe, Vermont								
Project # Segment	**Type of Project**	**Site Description Including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility and Priority**	**Other Social Benefits**	**Costs**	**Land Use Conversion**	**Potential Partners**
#17 Near intersection of North Hollow Road and Putnam Forest Road T6.07	Active Restoration	A 50 foot long berm just downstream of dam and North Hollow Road crossing.	Alternative analysis for berm removal.	Low priority due to short length but could be part of dam removal project.	Improve habitat and geomorphic stability	Cost of alternatives analysis for berm removal, excavation, and planting	Berm to floodplain.	VANR, LCPC. landowners
#18 Just downstream from North Hollow Road crossing. T6.07	Active Restoration	Reach is incised upstream of dam, but downstream of dam there is a bedrock gorge with many ledge grade controls that can prevent down cutting of bed. However, dam is a fish passage issue and is holding back sediment upstream.	Alternative analysis for dam removal	High priority due to fish passage issue and sediment retention.	Improve habitat and geomorphic stability	Cost of alternative analysis and dam destruction	Dam to natural stream channel	VANR, LCPC, landowners

Table 10. Moss Glen Brook Site Level Opportunities for Restoration and Protection Stowe, Vermont								
Project # Segment	**Type of Project**	**Site Description Including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility and Priority**	**Other Social Benefits**	**Costs**	**Land Use Conversion**	**Potential Partners**
#1 Stagecoach Road crossing T8.01-A	Active Restoration	Stagecoach Road has a double culvert that is undersized and mostly incompatible using the geomorphic screening tool. Deposition and scour are also issues with the culverts.	Replacement of double culverts	High priority	Improved geomorphic stability	Moderate cost for replacement	Unknown	Town of Stowe, VANR, LCPC
#2 From confluence with the Little River and upstream about 1,200. T8.01-A	Passive Restoration	Lack of adequate buffer on both sides due to agricultural fields. Buffer less than 25 feet mostly at downstream end on southern bank. Double culvert at Stagecoach Road crosses in this section. Erosion on outside bend upstream of confluence.	Protect River Corridor through river corridor easement or CREP. Improve Riparian Buffer. Streamside plantings.	High Priority for stream plantings.	Flood and sediment attenuation. Prevent erosion, improve habitat and reduce water temperature	Low cost for plantings	Agricultural to forested	VANR, LCPC, landowners, CREP, land trust

Table 10. Moss Glen Brook Site Level Opportunities for Restoration and Protection
Stowe, Vermont

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Land Use Conversion	Potential Partners
#3 From Pucker Street bridge to 1, 050 feet upstream of reach break where corridors become forested. T8.01-B and T8.02-A	Passive Restoration	Buffer less than 25 feet on both sides for 1,300 feet and then on the northern side for about another 900 feet along pasture fields. Channel has significant erosion on outside bends. Area with no buffer in T8.02-A has been straightened and has extensive erosion along the bank.	Protect river corridor through corridor easement or CREP. Improve Riparian Buffer. Streamside plantings.	High Priority for stream plantings in both segments. T8.02-A is not incising anymore, but the channel is over wide and there is significant aggradation and planform adjustment occurring.	Flood and sediment attenuation. Prevent erosion, improve habitat and reduce water temperature	Low cost for plantings	Agricultural to forested	VANR, LCPC, landowners, CREP, land trust
#4 Adjacent to Pucker Street T8.02-B and T8.03	Passive Restoration	Dominant buffer width is 26-50 feet in both segments. In T8.03, there is about 500 feet of buffer less than 25 feet in width. Well forested on southern side.	Protect river corridor through corridor easement or CREP. Buffer restoration – Natural Regeneration: Increase buffer width along crop field to extent feasible with low cost plantings or let vegetation grow back on its own.	High Priority due to high historic incision and stream type departures from "C" to "F".	Improved water quality.	Low cost	Agricultural land to forested	VANR, LCPC, landowners, CREP, land trust

7.4 Next Steps

There are many opportunities to restore the Little River and its tributaries to a stable condition. Types of reach level and site level projects that have been identified in this plan include river corridor protection, streamside plants, retrofit and/or replacement of stream crossings, and dam removal. On the watershed level, the development and implementation of fluvial erosion hazard zones is recommended to avoid conflicts regarding land use and to save money spent on flood damage and river maintenance. The Town of Stowe could pursue the opportunity to work with the LCPC and the Vermont River Management Program to develop fluvial erosion hazard zones for the land surrounding the Little River and its tributaries. The following are recommendations for next steps:

1. Outreach to private landowners and the public about the plan and potential restoration and protection opportunities to be completed by the State and/or LCPC.
2. Town, State, and LCPC representatives meet to discuss the various restoration and protection opportunities and set priorities for action.
3. Meetings to be held with additional partners (Lamoille County Natural Resources Conservation District, Department of Agriculture, Natural Resources Conservation Service, Vermont Agency of Transportation, etc.) to discuss implementation of priority projects.
4. Summary and prioritization of potential projects.
5. Implementation of priority projects with project partners and landowners.

For additional information about fluvial erosion hazard (FEH) zones or project development, please contact the LCPC:

Lamoille County Planning Commission
632 LaPorte Road
Morrisville, VT 05661
(802)888-4548
lcpc@lcpcvt.org

8.0 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, 2004, 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 raising 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 streambank 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.

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.

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 mainstem 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).

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 – 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.

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

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.

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.

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.

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.

Surficial sediment/geology – Sediment that lies on top of bedrock.

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

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.

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