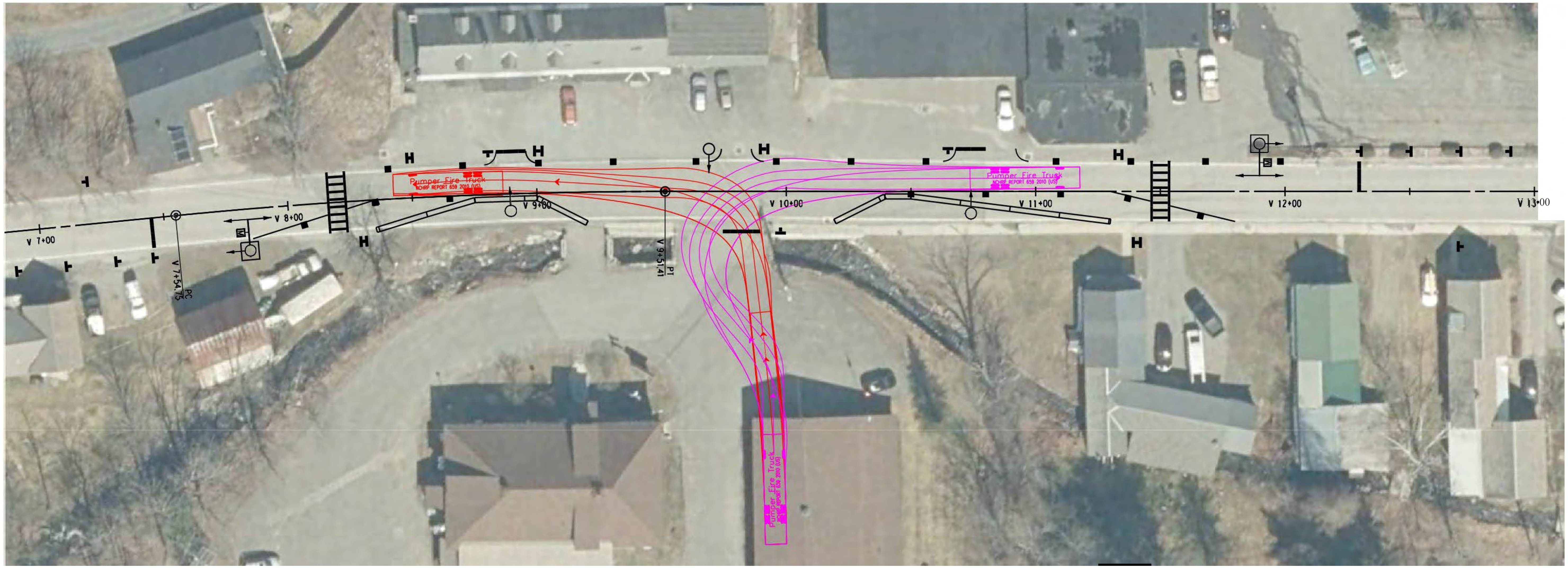
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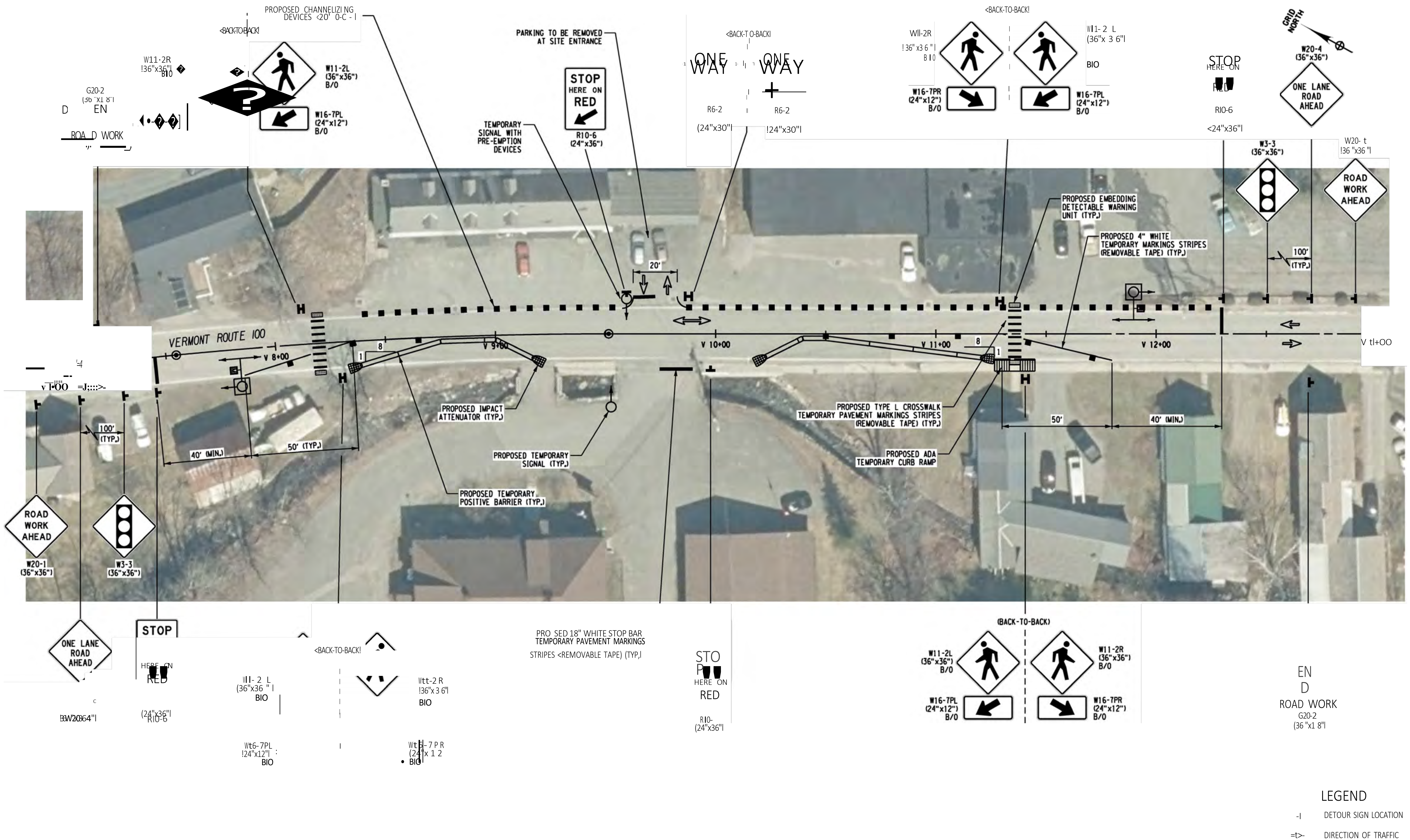

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APPENDIX 3: Meeting Minutes

1) Selectboard Minutes of 2/9/22 Alternatives Presentation

2) Selectboard Minutes of 8/25/21 Local Concerns Meeting

BENNINGTON & MONTPELIER, VERMONT
PO Box 139 | 150 Depot Street | Bennington, VT 05201 | mskeng.com | (802) 447-1402
Engineering • Survey • Permitting • Construction Administration

Whitingham Flood Resiliency Scoping Study

Local Concerns Meeting Minutes
February 9th, 2022, 6:30 PM
Videoconference

Attendees
Town of Whitingham Selectboard
Gig Zboray, Town of Whitingham
John Bennett, Windham Regional Commission
Andrew Rodriguez, MSK
Joe Bartlett , FEA
Evan Fitzgerald , FEA

AGENDA

1. *Introductions*

2. *Presentation of Alternatives*
MSK described all three alternatives

- Alternative 1 (No build): Would not require construction, and would not increase the areas flood resiliency.

- Alternative 2 (56-foot culvert): Remove the existing stone bridge and replace the existing culvert with a new 56' foot long by 16' foot wide culvert. However, parking would be reduced due to the widening of the channel.

- Alternative 3 (96-foot culvert): Remove the existing stone bridge and replace the existing culvert with a new 96' foot long by 16' wide culvert. This option would not reduce on site parking.

3. *Matrix Review*

MSK went thru the alternatives matrix and fielded questions from the attendants

4. *Discussion*
As part of the meeting, concerns were raised about river flow restrictions beyond the project scope; namely the culvert under the intersection of VT 112 & VT 100. There was a concern raised that this project would increase flows to this restricted section.

It was determined that his culvert was out of the project scope but FEA would perform a preliminary review to assess the projects impact

5. *Alternative Selection*

After brief discussion from the Selectboard, Alternative 2 (the 56-foot culvert), was selected as it addresses the project needs while being the lowest cost build option.

6. *Meeting Conclusion*

Town of Whitingham
Office of the Selectboard

MINUTES OF AUGUST 25, 2021

These Minutes are considered a DRAFT until accepted into the public record (with any corrections noted) at a future meeting of the Whitingham Selectboard.

The Whitingham Selectboard held a regular meeting at 6:30pm in the dining hall of the Whitingham Municipal Center on Wednesday, August 25, 2021.

Selectboard members present: Scott Reed, Chair; Craig Hammer, Vice Chair; and Chris Walling. James Weber attended remotely.

Others present: Gig Zboray, Selectboard Office Administrator; Almira Aekus, Clerk/Treasurer; Stan Janovsky, Jr., Road Commissioner; John Bennett, WRC; Andrew Rodriguez of MSK Engineers; Joe Bartlett of Fitzgerald Environmental; Lyman Tefft, resident; Cheryl Rusin and Elizabeth McEwen of Voices of Hope; Tyler Lederer from Valley News.

Call to Order. Additions or Changes to Agenda
Scott Reed called the meeting to order at 6:33pm. There were minor changes to the agenda since it was posted. Selectboard vacancy was moved to after the sewer rates.

Hearing of visitors (for concerns not on the agenda)
None

Engineers to explain project and hear public concerns regarding hazard mitigation project
Gig introduced John Bennett of the Windham Regional Commission, our Municipal Project Manager for this flood resiliency project. MSK Engineers have been working on a scoping study of the proposed hazard mitigation projects in Jacksonville. Part of the process is to hold a hearing of local concerns. Various questions were asked by those in attendance and answered by the engineers.

Voices of Hope: Elizabeth McEwen to discuss their program
Voices of Hope is a volunteer organization that provides resources to people regarding substance misuse disorders. Their main goal is to make people aware that help is available and to work towards removing the stigma of addiction. Gig will post information about the group and a website link on the town website when their site becomes live.

Highway: review and sign access permit
Mr. Janovsky presented an access permit for Richard Peters with the recommendation that the board approve it. **A motion was made by Chris Walling to approve and sign the access permit for Richard Peters at 625 Merrifield Road, seconded by Craig Hammer, all in favor.**

Sewer: set the rate for the current fiscal year

Based on the budget prepared by the Town Treasurer it was recommended that the board set the sewer rate at $1,208 per EU (Equivalent Unit). This represents a less than 10% increase over last year's rate of $1,100 per EU. The new rate continues to increase the capital improvements balance for future bond payments. The board members are reluctant to raise the rates but feel they have no choice. It is not an easy decision, but unfortunately it needs to be made. **A motion was made by Scott Reed to set the 2021/22 sewer rate at $1,208 per Equivalent Unit as recommended by the Town Treasurer, seconded by Chris Walling, Craig Hammer in favor, James Weber voted no. Motion passed.**

Gig noted that Michael Smith of Weston & Sampson engineers met with her and Dave DiCantio and state officials and then came down to inspect the Jacksonville media. After his inspection he wrote a letter to the state officials verifying that the condition of the media at the Jacksonville Plant is in working order sufficient to meet our permit requirements until the refurbishment project can be completed.

Mr. Janovsky questioned if the board is considering extending the sewer lines at any time. Much discussion ensued. It is such a huge undertaking. He recommended that if the sewer is eventually extended beyond village limits that zoning be changed to allow one-acre parcels in the new sewer area.

Selectboard Vacancy

A vacancy on the Selectboard was created with the resignation of Phil Edelstein in July.

Mr. Lyman Tefft submitted an email of interest. He told the board he has tried many years to get on the board, he would like to do what he can to help make the town more affordable.

Approval of Payables Warrant – August 26, 2021

A motion was made by Craig Hammer to approve Payables Warrant #W2210 dated August 26, 2021, seconded by Chris Walling, all in favor.

Approval of Payroll Warrant – August 26, 2021

A motion was made by Craig Hammer to approve Payroll Warrant #W2209 dated August 26, 2021, seconded by Chris Walling, all in favor.

Approve Minutes of August 11 and 16, 2021

A motion was made by Scott Reed to accept the Minutes of August 11 and 16, 2021, as written, seconded by Chris Walling, all in favor.

Other Business

Gig noted that with the county portion ($208,043.99) of ARPA funds we are expecting a total of $320,164.57. To date we have received $56,060.29 of the town allocation, another payment in the same amount is expected in August 2022. The county payment is expected in 2 equal payments in August/September of 2021 and 2022. We are still not quite clear on all the mandates regarding how this money can be spent.

Brook trout: The Native Fish Coalition would like to post a sign along the brook in front of the Municipal Center and possibly in the parking lot by the Jacksonville Church (and perhaps other locations in town) stating that there are native brook trout in the waters. Sample signage was reviewed. The board approved of the coalition posting the signage in various locations.

Executive Session

A motion was made by Chris Walling to enter Executive Session to evaluate potential public officials under the provisions of Title 1, Section 313(a)(3) of the Vermont Statutes, seconded by Craig Hammer, all in favor.

Executive session was exited at 7:43pm.

Mr. Greg Brown sent a text to Gig just before the meeting started stating his interest in being appointed to the Selectboard. He served on the board for over 15 years and has kept himself informed on the issues. Gig had a digital copy of his prior letter of interest that Mr. Brown asked her to submit to the board.

A motion was made by Chris Walling to appoint Greg Brown to fill the vacancy on the Selectboard until Town Meeting 2022, seconded by Craig Hammer, all in favor. Besides his years of prior experience on the board Selectboard members thought Mr. Brown would offer great help on the sewer project.

Adjourn

A motion was made by Scott Reed to adjourn, seconded by Craig Hammer, all in favor.

Scott Reed adjourned the meeting at 7:44 pm.

Respectfully submitted,

~Gig Zboray

APPENDIX 4

River Corridor Plan for the East Branch of the North River in Halifax and Whitingham,VT

December 21, 2017

Prepared by:

Fitzgerald Environmental Associates, LLC.
18 Severance Green, Suite 203
Colchester, VT 05446

Fitzgerald Environmental Associates, LLC.
Applied Watershed Science & Ecology

Prepared under contract to:

Windham Regional Commission
139 Main Street, Suite 505
Brattleboro VT, 05301

WINDHAM REGIONAL COMMISSION

Appendices:

List of Figures

List of Tables

Executive Summary

The East Branch of the North River drains approximately 40 square miles in southern Vermont, joining the West Branch of the North River mainstem in Colrain, Massachusetts from which the mainstem eventually empties into the Deerfield River in Shelburne, Massachusetts. The Vermont portion of the East Branch watershed is located in the Towns of Wilmington, Marlboro, Whitingham, and Halifax. The completion of a River Corridor Plan (RCP) for the East Branch North River watershed was identified as a top priority in the Deerfield River and Southern Connecticut River Tributaries of Vermont Tactical Basin Plan (VTDEC, 2014). Tropical Storm Irene in 2011 was a major flood in the North River watershed and caused widespread damage along the East Branch, especially in the Village of Jacksonville.

Fitzgerald Environmental Associations, LLC (FEA) was hired in 2016 by the Windham Regional Commission (WRC) to complete a River Corridor Plan including Phase 1 and Phase 2 Stream Geomorphic Assessments (SGA) for the East Branch North River watershed. The Phase 1 and Phase 2 assessments were completed in spring-fall of 2016. This report describes the results of the Phase 1 and Phase 2 studies and the East Branch North River Corridor Plan. The plan objectives are described below:

1) Develop baseline watershed and reach-scale data for the study reaches.
2) Identify river reaches where more detailed field data collection (Phase 2) is needed.
3) Develop a basis for understanding the overall causes of channel instability and habitat degradation along the river corridors in the watershed.
4) Collect the information needed to improve river corridor mapping in the study area.
5) Develop a list of preliminary river corridor restoration projects that can be further developed in the future to mitigate flood and erosion hazards and improve ecological integrity and water quality.
6) Prioritize river corridor restoration projects for the watershed.
7) Develop five (5) project packets for high priority restoration sites.

Below is a summary of key findings from the Phase 1 and Phase 2 SGA and River Corridor Plan: <u>Phase</u>

<u>1 Study</u>

- A total of 15 reaches along 16 river miles were delineated during the Phase 1 SGA analysis. Full Phase 1 data and windshield survey data were collected by FEA for these portions of the East Branch, Branch Brook, and Hager Brook.
- The Phase 1 SGA approach resulted in watershed-scale data about the landscape (e.g., soils and land cover) and the stream channel (e.g., slope and form), providing a basis for understanding the natural and human-impacted conditions within the watershed. The Phase 1 data also aided in the identification of specific stressors affecting the physical conditions of the stream channels and structures (e.g., bridges and culverts, bank armoring, etc.).
- Three (3) reaches are found in a confined valley setting that would normally support sediment and transport channels with A or B-type channel geometry. Six (6) of the reaches are found in narrow valleys with C or B-type channel geometry. The remaining Six (6) reaches are found in an unconfined valley setting with meandering, depositional, C-type channel geometry.

- Approximately 84% of the watershed is forested, with agricultural land use representing approximately 8% of the watershed. Developed lands represent 5% of the watershed.
- Impact ratings were developed for each reach using the Phase 1 parameters representing four classes of watershed and reach-scale impacts: 1) Land Cover and Reach Hydrology; 2) Channel Modifications; 3) Floodplain Modifications and Planform Changes; and 4) Bed and Bank Conditions. Out of a total possible impact score of 32, the maximum score was 22 (poor) and the minimum score was 1 (reference).
- Based on the Phase 1 impact ratings, a total of eight (8) high-priority reaches covering 8.7 miles on the East Branch North River and on Branch Brook were selected for Phase 2 assessment.

Phase 2 Study

- During the Phase 2 field assessments, the 8 reaches were further subdivided into 13 segments based on variability in stream type, channel slope and confinement, and other factors. Two (2) segments were not fully assessed due to impoundment from beaver dams (M04.A) and a bedrock gorge (M03.B).
- Tropical Storm Irene in 2011 was a major flood along the East Branch North River and Branch Brook. The Village of Jacksonville located along the East Branch experienced significant inundation and erosion damages.
- The channels of the East Branch North River and Branch Brook are still adjusting their width, depth, and planform to the following historical and ongoing impacts: 1) aggradation of sediment in the valleys due to European settlement and deforestation that occurred during the 1700's and 1800's; 2) channel straightening, dredging, and corridor encroachment associated with adjacent roads, agriculture, and other land uses; 3) floods in recent years which have triggered valley erosion, sending increased volumes of sediment and woody debris into the lower valleys in Halifax and Whitingham.
- Overall Phase 2 geomorphic ratings indicate a range of river stability from poor to good along the study reaches. The two “poor” reaches were located within the Village of Jacksonville where the channel is highly encroached by adjacent development and has been historically straightened. One “good” reach is located upstream of the Village where the channel flows through a forested floodplain and is stable. The remainder of the watershed was rated as “fair” due to incision and some areas of active channel adjustment.
- 20 bridges and 1 culvert were assessed for geomorphic compatibility and aquatic organism passage (AOP) as part of the Phase 2 SGA work. Thirteen (13) of the bridges had spans less than the reference bankfull channel width, indicating an increased degree of structure vulnerability to flooding and erosion. The culvert represented a significant bankfull constriction (54%), and had reduced aquatic organism passage (AOP). The summary of structures in this report, including the reference bankfull channel width listed for each one, provides a means for towns to understand the relative flood vulnerability and prioritize structure replacements with these criteria in mind.

River Corridor Planning and Overall Flood Resiliency Recommendations

- Based on flood damages incurred during Tropical Storm Irene and previous floods in the study area, the East Branch North River and Branch Brook watersheds are vulnerable to flooding during prolonged rainstorms and flashy thunderstorms. The National Flood Insurance Program (NFIP) has developed approximate 100-year floodplains near the confluence of Branch Brook and the East Branch North River and within the Village of Jacksonville; no detailed flood study has been completed within the watershed.
- River Corridor protection ordinances were incorporated into the Town of Halifax Zoning Regulations in 2016. River corridor protection ordinances should also be considered by the Whitingham to better map flood and erosion risks for both the safety and protection of their citizens, and the infrastructure controlled by the municipality.
- The current Emergency Relief and Assistance Fund (ERAF) rate for state aid to cover flood damage costs in Whitingham is 7.5%. Whitingham does not have an approved Local Hazard Mitigation Plan or River Corridor Protection. If these two actions were implemented, the ERAF rate would increase to the maximum of 17.5% for both towns. The Town of Halifax has the maximum ERAF rate of 17.5% as all five necessary measures have been implemented, including river corridor protection zoning.
- Site level approaches to river corridor restoration were evaluated in detail at the reach scale, and are organized in the report by reach. The projects were developed based on the Phase 2 results and watershed-scale mapping of stressors on channel stability. The list of projects is intended to provide a “roadmap” of restoration projects that will reduce future flood hazards and improve ecological conditions in the river corridor. This effort resulted in the identification of 30 restoration project areas, including 10 projects that do not require significant further study (i.e., passive approaches such as buffer plantings and corridor protection), and 20 projects requiring further feasibility study or engineering design (i.e., active restoration approaches such as bridge replacements).
- Project packets were developed for five (5) of the high-priority sites. This process required additional site visits and landowner outreach, mapping, field surveys, and other data collection. The project packets include more detailed information for project implementation, evaluation of alternatives for flood mitigation in the Village of Jacksonville, cost estimates, and potential funding partners.

1.0 Project and Watershed Background

1.1 Project Introduction and Study Goals

1.1.1 Project Introduction

In 2016, the Windham Regional Commission (WRC) and the Vermont Department of Environmental Conservation (VTDEC) identified the East Branch of the North River and its tributaries Branch Brook and Hager Brook in southern Vermont for assessment of fluvial geomorphic and aquatic habitat conditions. Flooding and erosion damage sustained during Tropical Storm Irene (TSI) in the Towns of Halifax and Whitingham influenced the selection of these tributaries for further study. Infrastructure along the river and tributaries was severely impacted by flooding and erosion, and therefore this information will serve to help the towns better understand existing flood vulnerabilities, and plan for future improvements with flood risks in mind.

The Windham Regional Commission (WRC) received a grant from the Vermont Agency of Natural Resources (Ecosystem Restoration Program) to conduct Phase 1 and Phase 2 Geomorphic Assessments and develop a River Corridor Plan (RCP) in the North River watershed. Fitzgerald Environmental Associates, LLC. (FEA) was retained by WRC in 2016 to complete river assessments on the East Branch of the North River, Branch Brook, and Hager Brook following the Phase 1 Stream Geomorphic Assessment (SGA) Protocols (VTDEC, 2009) developed by the VTDEC. FEA used the Stream Geomorphic Assessment Tool (SGAT) to develop the baseline GIS data for the watershed in 2016. A total of 15 reaches along 16 river miles were assessed during the Phase 1 analysis.

Following this study, a subset of the Phase 1 reaches was selected for field-based, Phase 2 SGA data collection. FEA completed the Phase 2 field work in 2016 for 8 reaches (approximately 8.7 river miles) along the East Branch of the North River and Branch Brook and developed a RCP for these reaches. Bridge and Culvert Assessments were completed for all the Phase 2 reaches. This report summarizes watershed background information, SGA results, and the RCP into one planning document.

1.1.2 Study Goals

Watershed restoration projects are most successful when carried out within a context for understanding how reach and watershed-scale stressors cause channel instability. The VTDEC SGA Protocols and River Corridor Planning Guide provides sound, scientifically-defensible methods for identifying stressors on channel stability and restoration projects that will address them appropriately (VTANR, 2010). The overall goal of the VTDEC Rivers Program 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,” (VTANR, 2010) achieved through:

- Fluvial erosion hazard mitigation;
- Sediment and nutrient load reduction; and
- Aquatic and riparian protection and restoration

The Phase 1 SGA approach results in watershed-scale data about the landscape (e.g., soils and land cover) and the stream channel (e.g., slope and form), providing a basis for understanding the natural and human-impacted conditions within the watershed. The SGA data also aids in the identification of specific stressors affecting the physical conditions of the stream channels and structures (e.g., bridges and culverts). Ultimately, the Phase 1 results help guide planners in selecting reaches for more detailed Phase 2 data collection where this information can be valuable for flood vulnerability mapping, identification of river restoration projects, and long-term river corridor planning. The goal of the Phase 2 and RCP effort is to provide:

1) A basis for understanding the overall causes of channel instability and habitat degradation along the river corridors in the watershed.
2) A list of preliminary corridor restoration projects that can be further developed in the future to mitigate flood and erosion hazards.
3) Information needed to map fluvial erosion hazard zones in Halifax and Whitingham.

1.2 Background Watershed Information

1.2.1 Geographic Setting and Land Use History

The North River watershed drains approximately 93 square miles of Vermont and Massachusetts. The East Branch North River watershed drains approximately 54 square miles in Vermont and Massachusetts. The Vermont portion of the East Branch North River watershed flows from shortly upstream of Ryder Pond in the Town of Whitingham and drains approximately 40 square miles within the Towns of Wilmington, Marlboro, Whitingham and Halifax (Figure 1.1). The main stem and tributaries described in this report are located within the Towns of Whitingham and Halifax. Hager Brook drains approximately 3.7 square miles starting in the hills on the border of Massachusetts with the Town of Whitingham. Branch Brook drains 9.6 square miles flowing from the hills on the border of the Towns of Marlboro and Halifax (Figure 1.2).

Land cover data based on imagery from 2011 (Homer et al., 2015) are summarized in Table 1.1 and displayed in Figure 1.3. The East Branch North River, Branch Brook and Hager Brook are drained by rural watersheds, with forests representing the dominant land cover type (84%, 86% and 77% respectively). Agricultural lands cover approximately 8% of the mainstem watershed, however this is predominantly classified as pasture/hayfield, cultivated crops are not widespread in any of subwatersheds. The East Branch North River Mainstem flows through a relatively dense commercial and residential area as it passes through the Village of Jacksonville in the Town of Whitingham.

Table 1.1: Percent Land Cover for East Branch North River watershed.

Watershed	Drainage Area (mi^2)	Agriculture	Development	Forest	Open Water	Wetland
East Branch North River Mainstem	39.54	8%	5%	84%	0%	3%
Branch Brook	9.58	5%	4%	86%	0%	4%
Hager Brook	3.70	13%	5%	77%	1%	4%

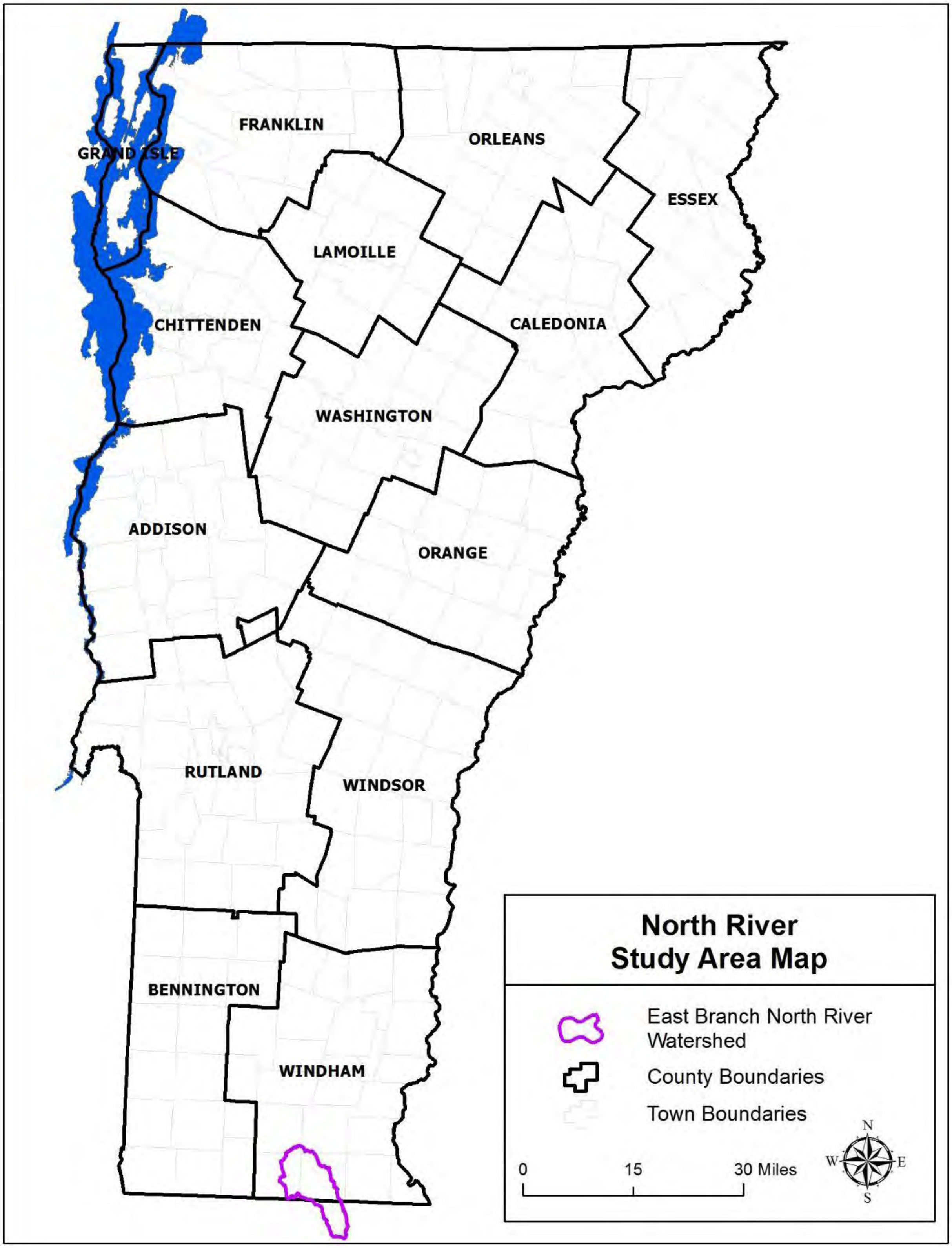


Figure 1.1: Location map for the East Branch North River watershed.

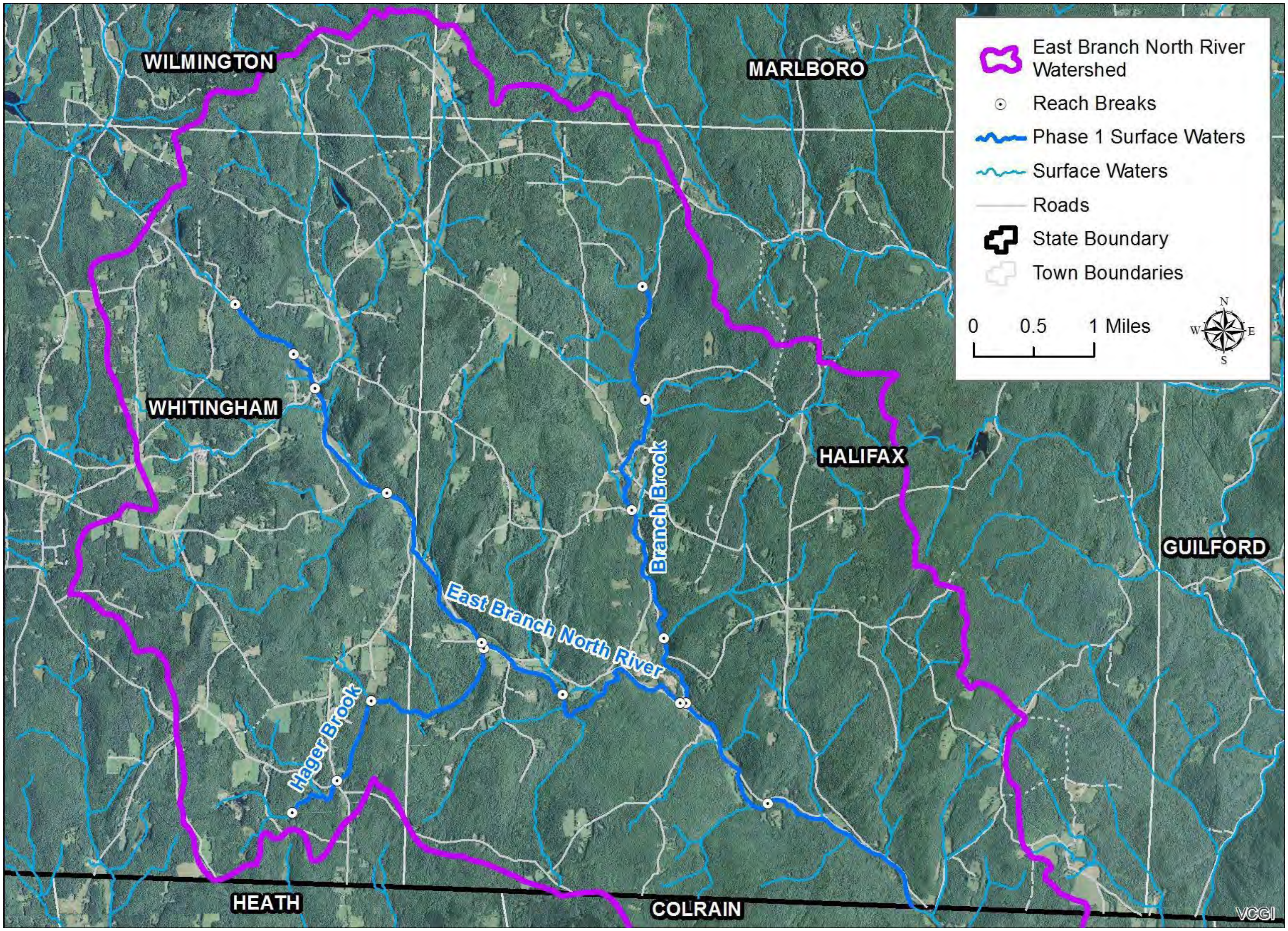


Figure 1.2: East Branch North River watershed, Phase 1 surface waters, and town boundaries.

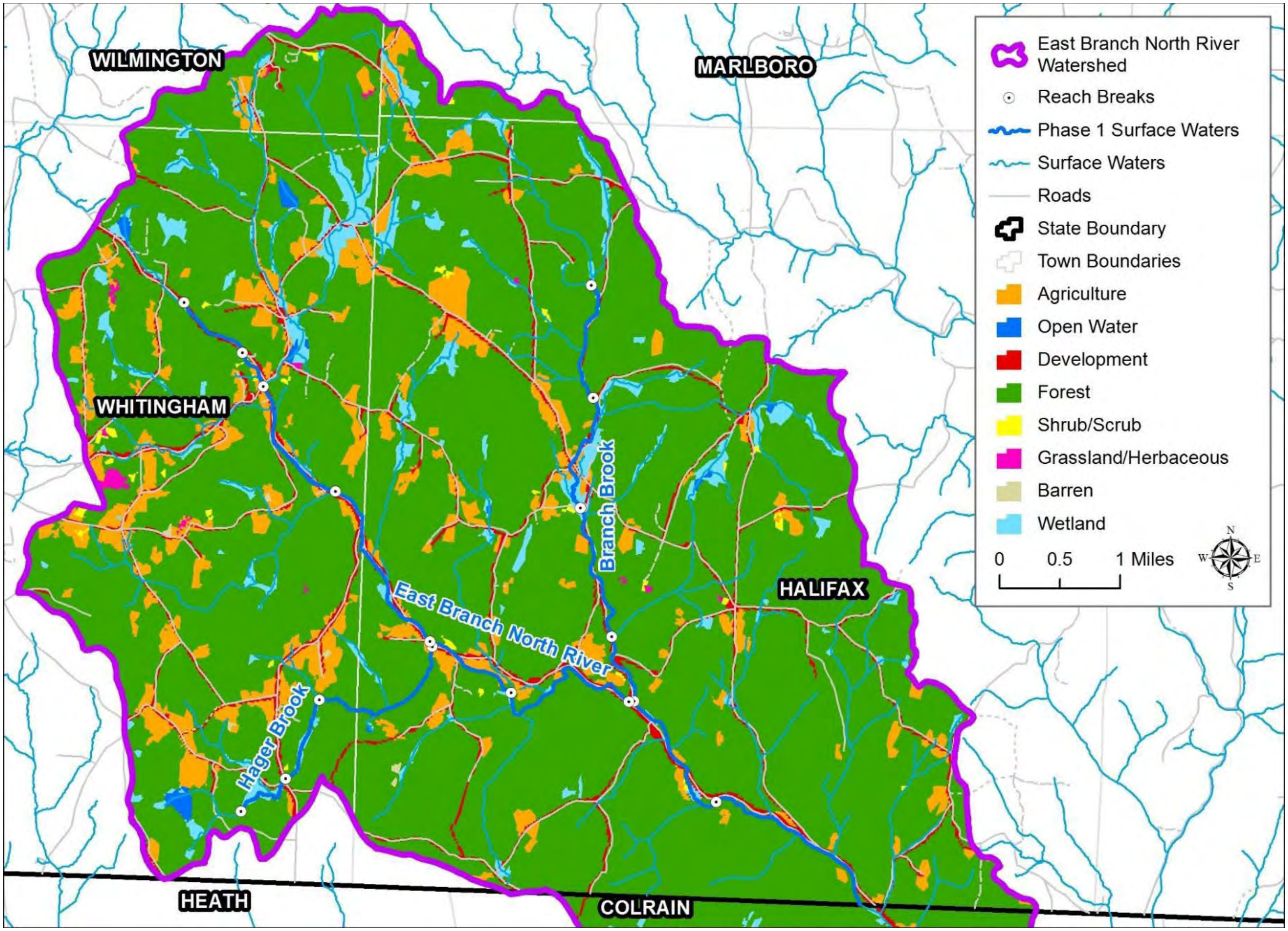


Figure 1.3: Land cover data for the East Branch North River watershed.

Historically, the impacts of agricultural practices on the Vermont landscape left a lasting legacy on waterways like East Branch North River. Prior to the deforestation associated with human settlement, the watershed would have been a mixture of deciduous forest on the valley floors, coniferous forest along the mountain spines, and a mixture of both along the slopes. Deforestation and grazing, largely from sheep farms, likely left over 90 percent of the watershed devoid of trees at one time or another (Albers, 2000). This landscape change had a tremendous impact on waterways like the East Branch North River. Exposed, highly-erodible soils (e.g., glacial tills) on steep slopes were carried to the valley floors and aggraded on river bottoms; a legacy that still influences the way Vermont's rivers are managed today.

As Vermont's farmers began to move to the Midwest in search of more productive farmland in the mid to late 1800's, the deciduous forests along the mountain slopes began to recover (Albers, 2000). Throughout the early and mid-1900's, as more family farms on marginal lands were given up, the forests continued to recover. Today, approximately 84 percent of the watershed is covered by forest. With the increasing tourism sector in the state, and the need for lumber for second-homes and construction, forestry has replaced agriculture in many of the rural hill slopes of Vermont.

1.2.2 Geologic Setting

The underlying geology of the East Branch North River watershed is comprised of a range of bedrock types. The lower portion of the study area contains a mixture of metasedimentary phyllites metalimestones, and quartzites. Upstream of the Branch Brook confluence the watershed transitions to metaplutonic and metavolcanics schist, amphibolite, granofels, and granite (Ratcliffe et al., 2011).

Surficial geologic deposits in the East Branch North River watershed were governed largely by glacial activity. During the Wisconsin glaciation, glaciers one mile in thickness extended across New England, reaching their maximum extents approximately 20,000 years ago. This glacial event left the Green Mountains with a physical imprint that is clearly evident today. In the East Branch North River watershed dense till, glacial till, and outwash areas reflect the dynamic nature with which glaciers shaped the landscape (Figure 1.4). Most of the surficial geology of the watershed is dominated by till and the stream corridors are primarily outwash and alluvium. The resultant soils in the North River watershed are primarily fine sandy loams, many of which are very stony (Marlow, Houghtonville, Colton, Berkshire-Tunbridge, Mundal, and Rawsonville-Hogback). Worden loamy soils are prevalent in the western half of the watershed. High elevation organic soils (Markey muck and Lupton mucky peat) are scattered throughout the upper drainages.

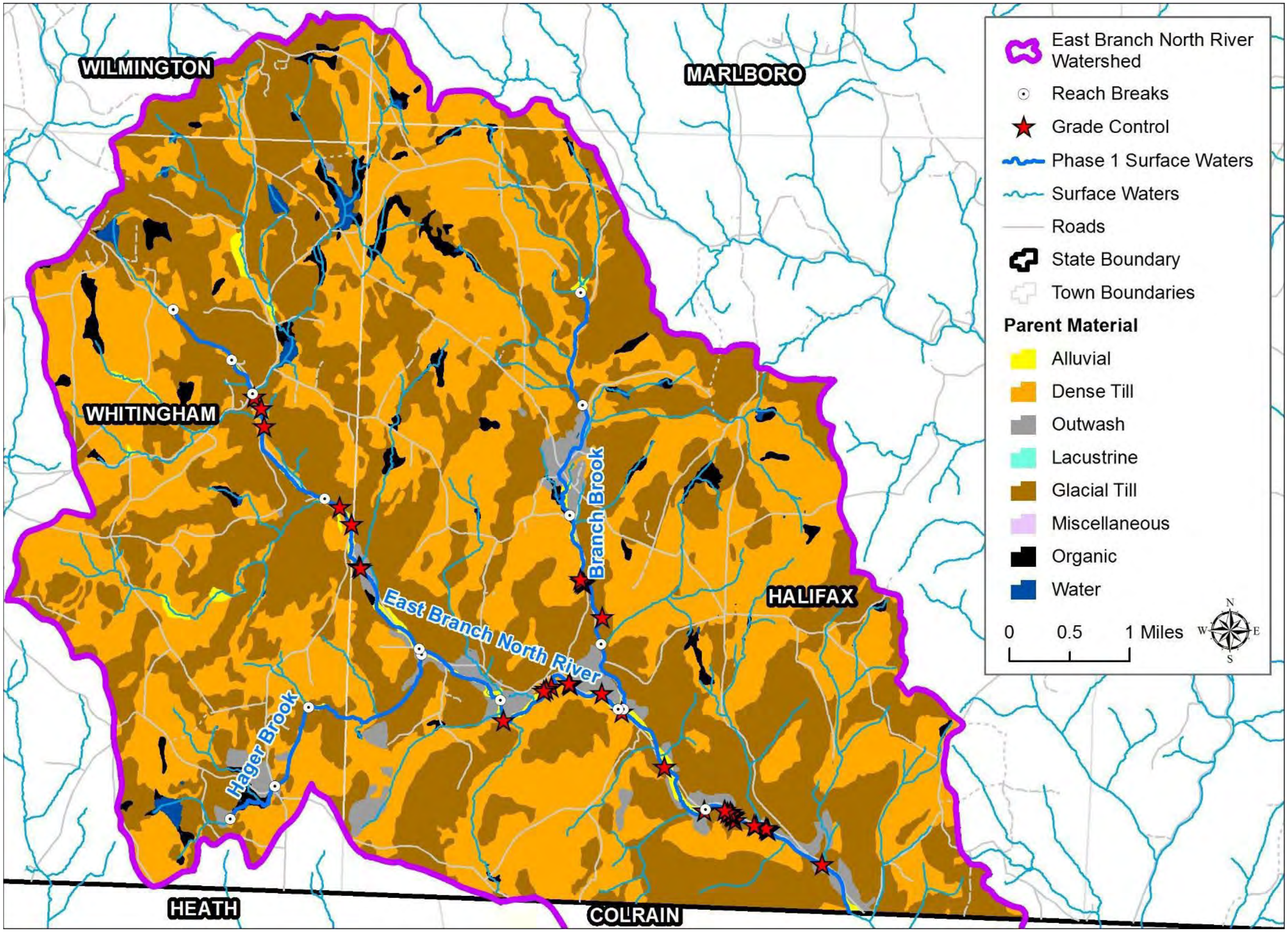


Figure 1.4: Parent surficial materials and grade controls in the East Branch North River watershed.

1.2.3 Geomorphic Setting

The East Branch North River Phase 1 study area contains two major tributaries (Branch Brook and Hager Brook). Average slopes for the study reaches are presented in Table 1.2. The first reach of the East Branch North River begins at the Massachusetts border and flows through a low gradient (1.4% slope) semi confined valley before climbing through a series of bedrock cascades near the top of the reach. The channel remains low gradient in reach M02 (1.1% slope), with a higher slope where the channel climbs through a series of bedrock cascades in reach M03 (1.82% slope). The middle reaches (M04 – M06) are low gradient streams flowing through historically unconfined valleys that have been narrowed by encroachment from VT 112 (1.2% average slope). Slope increases in the Village of Jacksonville where reach M07 flows through a very broad unconfined valley (3.2% slope). Above the Village, slope increases further in reach M08 (5.1% slope) and the valley is semi confined.

The first reaches of Branch Brook (T1.01 and T1.02) begin at the confluence with the East Branch of the North River at the intersection of VT 112 and Branch Road and flows through a historically unconfined valley that has been narrowed by encroachment from Branch Road. The channel climbs through a series of bedrock grade controls in reach T1.02 (1.9% slope). The upper reaches of Branch Brook (T1.03 and T1.04) begin at the intersection of Sprague Road and Branch Road and flow through a naturally unconfined valley that has been narrowed by encroachment from Brook Road. Reach T1.03 begins in a low gradient stretch that flows through beaver-influenced wetlands (1.4% slope) and the channel steepens in reach T1.04 (2.1% slope) nearer to the headwaters.

Hager Brook begins at the confluence with the East Branch of the North River between the intersections of Fowler Road and Smith Road with VT 112 and flows through an unconfined valley that has not been significantly narrowed by road encroachments. The lower reach (T2.01) is the steepest (4.3% slope) and becomes less steep in reaches T2.02 and T2.03 (1.8% average slope).

Table 1.2: Average channel slopes for major and sub tributaries.

Channel (SGA Reaches)	Average Slope
Lower East Branch North River (M01 – M06)	1.3%
Upper East Branch North River (M07 - M08)	4.1%
Branch Brook (T1.01 – T1.04)	1.8%
Hager Brook (T2.01 – T2.03)	2.6%

1.2.4 Hydrology and Flood History

The United States Geological Survey (USGS) has never operated a real-time flow monitoring gage on the East Branch of the North River. The USGS operates a real-time flow monitoring stations on the North River in Shattuckville MA and in nearby basins on the Deerfield River in Charlemont MA (upstream of North River confluence) and on the Green River in Colrain MA. These basins are all larger than the study watersheds and peak flows are regulated by impoundments to varying degrees; however, the peak flows recorded at these nearby stations are useful for estimating the size and frequency of flood events for the East Branch of the North River. Peak flow recurrence intervals for all nearby USGS stream gaging stations are shown below in Table 1.3. Peak flows were estimated for the East Branch North River study area using the USGS StreamStats program, which calculates flows from a statewide regression equation (Olson, 2014).

Table 1.3: Estimated Frequency and magnitude of flow events in gaged basins near Halifax, VT.

Return Frequency	Discharge (cfs)			
	[1]North River (Shattuckville, MA)	[1]Deerfield River (Charlemont, MA)	[2]Green River (Colrain, MA)	[3]East Branch North River at M02 (Halifax, VT)
Drainage Area (mi^2)	88	361	116	35
Data Period	1940-2013	1914-2013	1967-2015	None
2 year	4,890	11,000	2,440	1,340
5 year	8,170	18,600	3,860	2,090
10 year	11,000	25,100	5,070	2,660
25 year	15,300	35,100	6,490	3,500
50 year	19,200	44,000	8,620	4,230
100 year	23,800	54,300	10,600	5,000
200 year	29,000	66,100	12,800	5,860
500 year	37,300	84,600	16,400	7,150

Recurrence interval data sources: [1]Zarriello, 2017; [2]Olson, 2014; [3]USGS StreamStats

Figure 1.5: Floodwaters spilled out of the channel of the East Branch North River and flowed down VT 100 through Jacksonville, VT during Tropical Storm Irene in 2011 (Photo courtesy of G. Havreluk).

Tropical Storm Irene was a significant flood event in southern Vermont (Figure 1.5). The nearby USGS stream gaging stations recorded flows estimated at the 100-year flood on the Deerfield River and at the 200-year flood on the North River and Green River. Additional major floods (greater than the 25-year event) were recorded in 2006 in Shattuckville; 1915, 1928, 1938, 1948, 1987 in Charlemont; and 2005 in Colrain. Tropical Storm Irene produced the largest peak flows on record at the Shattuckville and Colrain monitoring stations. The September 21st, 1938 flood on the Deerfield River in Charlemont is estimated at a 100-year flood and had a peak stage approximately similar to T.S. Irene, with both flows affected by flow regulation at multiple reservoirs and power plants. Annual peak flows for the North River in Shattuckville MA are shown in Figure 1.6.

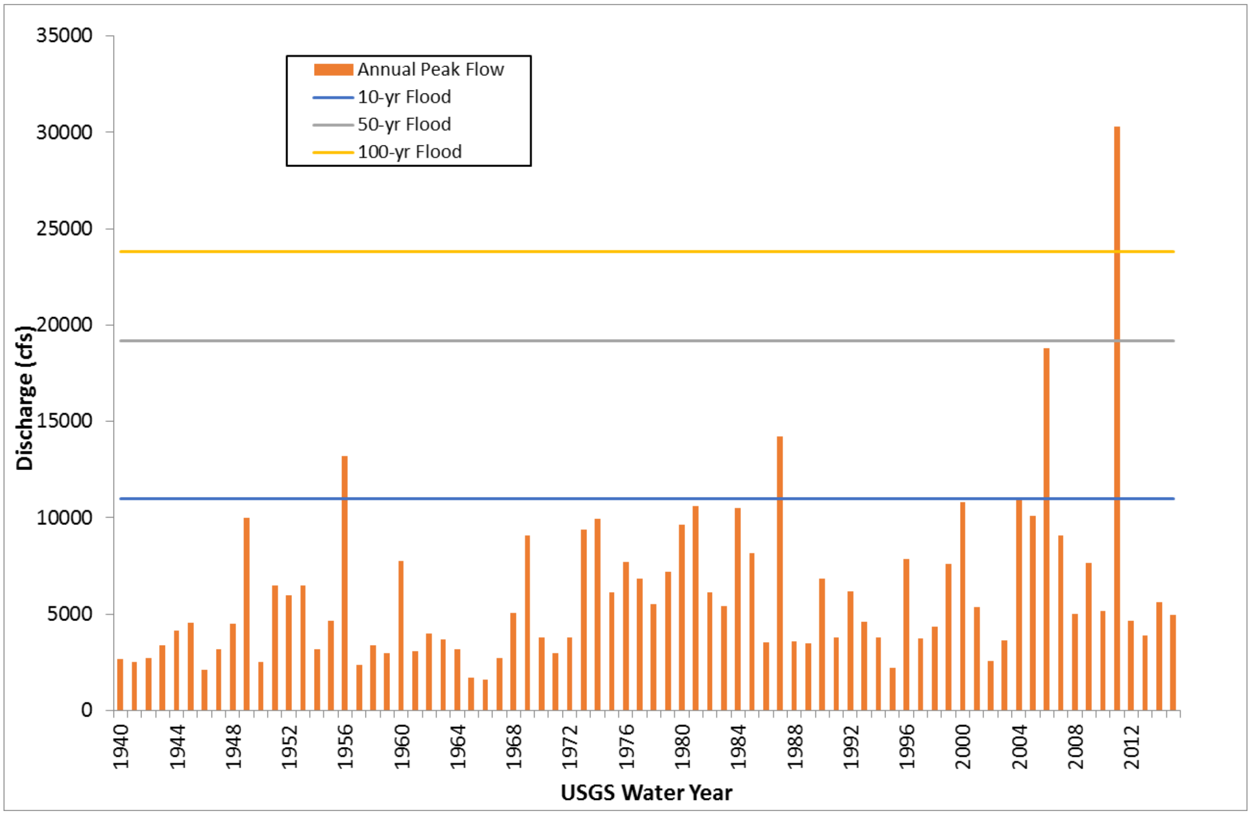


Figure 1.6: Annual peak streamflows from USGS gage on the North River in Shattuckville, MA.

1.2.5 Ecological Setting

Most of the East Branch North River watershed evaluated is located within the Southern Green Mountains (SM) biophysical region, with the lowest reaches extending into the Southern Vermont Piedmont (SP) biophysical region (Thompson and Sorenson, 2000). The SP region is found along the eastern border of Vermont and extends from White River Junction down to Massachusetts. It is characterized by gentle rolling hills and bedrock geology that supports Northern Hardwood Forest communities. Some areas of igneous intrusions (e.g., granitic plutons), such as Ascutney Mountain and Black Mountain to the west of Brattleboro, support rare communities such as the Pitch Pine-Oak-Heath community. Rich soils of loam and silt along the Connecticut River that once supported extensive areas of silver maple (*Acer saccharinum*) and Ostrich Fern (*Matteuccia struthiopteris*) were converted to agricultural use during European settlement in the late 18th century.

The SM region is found along the spine of the Green Mountains and low foothills to the east in the southern half of Vermont. Temperatures are cooler and precipitation is higher in this region. Bedrock is typically metamorphic, acidic, and non-calcareous. The natural communities in this region tend to be those with northern affinities that are best suited for colder temperatures. Boreal communities are found on the highest peaks where winter conditions are harshest. The slopes grade into the Northern Hardwood forest type at elevations of around 2,500 feet. Deep glacial till deposits cover most of the

SM region including the East Branch North River watershed. Glaciofluvial kame and outwash deposits common in the SM region are found throughout the river valleys. Elevations within the study area range from 540 feet at the Massachusetts border to around 2,300 feet in the hills south of Molly Stark State Park in Wilmington that drain the Gates Pond headwaters.

Macroinvertebrate assessments have been complete by the VT DEC Biomonitoring Division on the East Branch North River on reaches M02 and M06B. Fish community assessments were performed once each at sites on reaches M03C in 2003 and M01 in 2016 and found "fair" and "very good" fish communities respectively. Three (3) fish community assessments were completed at the M02 site, rating the health of the population as "good" in the mid-1990s and "very good" after 2007. Eleven (11) macroinvertebrate assessments were conducted at the M02 site between 1993 and 2015, including four (4) post-T.S. Irene assessments, and two (2) pre-T.S. Irene macroinvertebrate community assessments were conducted at the M06B site. The macroinvertebrate community was consistently "excellent" at the M02 site before and after T.S. Irene, except for one "good-fair" rating due to low macroinvertebrate density in an assessment conducted less than 2 months after T.S. Irene. Macroinvertebrate assessments conducted at the M06B site in 2003 and 2008, found "excellent" and "very good" communities respectively.

Small areas of wetland are scattered throughout the watersheds of the East Branch North River and its tributaries with a total land cover of approximately 3-4% of each watershed. Small wetlands are found along streams and small tributaries throughout the watershed.

2.0 Data Collection

2.1 Data Collection Methods

The Vermont River Management Program (RMP) has invested many person-years of effort into developing a state-of-the-art system of Stream Geomorphic Assessment (SGA) protocols. The SGA protocols are intended to be used by resource managers, community watershed groups, municipalities and others to identify how changes to land use affect hydro-geomorphic processes at the landscape and reach scale, and how these changes alter the physical structure and biological habitat of streams in Vermont. The SGA protocols have become a key tool in the prioritization of restoration projects that will 1) reduce sediment and nutrient loading to downstream receiving waters such as Lake Champlain and the Connecticut River, 2) reduce the risk of property damage from flooding and erosion, and 3) enhance the quality of in-stream biological habitat. The protocols are based on defensible scientific principles and have been tested widely in many watersheds throughout the state. Data collected for the East Branch North River watershed using the protocols formed the basis for preliminary project identification carried out during the Phase 2 SGA and River Corridor Planning efforts.

The SGA protocols include three phases (VTDEC, 2009):

- Phase 1: The Phase 1 SGA approach utilizes the Stream Geomorphic Assessment Tool (SGAT), a GIS extension developed by RMP for the collection of reach and watershed scale data. In addition to the GIS and remote sensing effort, a cursory field assessment ("windshield survey") is included for the verification of stream and valley forms, significant channel features and the location of man-made infrastructure. The Phase 1 SGA approach results in watershed-scale data about the landscape (e.g., soils and land cover) and the stream channel (e.g., slope and form), which provides a basis for understanding the natural and human-impacted conditions within the watershed. The SGA data also aids in the identification of specific stressors affecting the physical conditions of the stream channels and structures (e.g., bridges and culverts). Table 2.1 summarizes the parameters collected in Phase 1 using the Feature Indexing Tool (FIT), which include those utilized to develop the final impact ratings.

- Phase 2: The Phase 2 approach builds upon Phase 1 data through the collection of reach-specific data about the current physical conditions. Characterization of reach conditions utilizes a suite of quantitative (e.g., channel geometry, pebble counts) and qualitative (e.g., pool-riffle habitat) measurements to calculate two indices: Rapid Geomorphic Assessment (RGA) Score; and Rapid Habitat Assessment (RHA) score. Using the RGA scores in conjunction with knowledge about the background or "reference" conditions, a sensitivity rating is developed to predict the degree to which the channel will adjust to human and natural impacts in the future.

Table 2.1: Parameters collected with FIT.

Phase 1 Step	Phase 2 Step	Data Type	Impact	Sub-Impact
3.1	1.2	Point	Alluvial Fan	NA
3.2	1.6	Point	Grade Control	Dam Ledge Waterfall Weir
NA	3.3	Point	Mass Failure	NA
5.5	5.5	Point	Dredging	Dredging Gravel Mining Commercial Mining
NA	4.4	Point	Debris Jam	NA
NA	4.6	Point	Stormwater Input	NA
NA	4.9	Point	Beaver Dam	NA
NA	5.2	Point	Migration	Neck Cut Off Flood chute Avulsion Braiding
NA	5.3	Point	Steep Riffle or Head Cut	Head Cut Steep Riffle
NA	5.4	Point	Stream Crossing	Stream Ford Animal Crossing
NA	3.3	Point	Gully	NA
6.2	1.3	Line	Development	NA
6.1	1.3	Line	Encroachment	Berm Improved Path Road Railroad
5.3	3.1	Line	Bank Armoring or Revetment	Rip-Rap Hard Bank Other

Table 2.1: Parameters collected with FIT.

Phase 1 Step	Phase 2 Step	Data Type	Impact	Sub-Impact
7.2	3.1	Line	Erosion	NA
5.4	5.5	Line	Straightening	Straightening With Windrowing

- Phase 3: Phase 3 surveys involve the collection of detailed, reach-scale survey data to verify or build upon Phase 2 data. These surveys are typically carried out prior to project development for an "active" channel management approach (e.g., floodplain restoration), or for long-term monitoring purposes.

FEA developed a SGAT geodatabase using the SGAT 10.3 toolbar. The subwatersheds, valley walls, and meander centerline themes were created for the study reaches and reviewed by VTDEC staff. The VTANR Data Management System (DMS) database was populated from these themes and reference stream types were assigned. The remaining Phase 1 data was collected remotely by FEA and through windshield surveys for reaches along 8.5 river miles. All major human impacts and natural features were indexed in a GIS using the FIT.

2.2 Quality Assurance

The VTDEC Quality Assurance (QA) protocols outlined in the SGA protocols (VTDEC, 2009) were followed in order to ensure a complete and accurate dataset. FEA and VTDEC shared responsibility for QA for the SGAT shapefiles and the finalized Phase 1 and Phase 2 datasets. The DMS database for all Phase 1 assessed reaches in the watershed was finalized in December 2016. The DMS database for all Phase 2 assessed reaches was finalized in May 2017. QA/QC correspondences between Shannon Pytlik (VTDEC River Management) and FEA are shown below.

To: Fitzgerald Environmental
From: Shannon Pytlik, VTDEC River Management
Date: 11/29/2016
I took a look at the North River Phase 1 data and I only have a few minor comments: M02 has noted a 4400 foot long berm was that entered correctly? M03 also a long berm noted maybe it uploaded improperly can you double check the data? If its accurate that's a long berm! M08 – This is noted as an A stream type yet 95% straightened. It might be naturally straight we don't normally see A stream types with 5% slope and bedrock channels that are straightened.

To: Shannon Pytlik, VTDEC River Management
From: Fitzgerald Environmental
Date: 12/6/2016
We updated the Phase 1 FIT and DMS based on your comments. The "berm" along M02 and M03 was changed over to road encroachment and we removed most of the straightening from M08.

2.3 Bridge and Culvert Assessments

FEA conducted bridge and culvert surveys on all private and public structures within the Phase 2 study area. The Bridge and Culvert Assessment and Survey Protocols specified in Appendix G of the Vermont Stream Geomorphic Assessment Handbook (VTDEC, 2009) were followed. Latitude and Longitude of each structure was recorded in the field with a GPS unit or digitized based on aerial imagery. The assessment included various photographs documenting the condition of each structure.

2.4 Stressor and Departure Analysis

FEA followed the VTDEC methods for developing river corridor plans as outlined in the Vermont River Corridor Planning Guide (VTANR, 2010). This technical guide is directed towards river scientists, planners, and engineers engaged in finding economically and ecologically sustainable solutions to the conflicts between human investments and river dynamics. The guide provides explanations for the following:

- River science and societal benefits of managing streams in a sustainable manner toward equilibrium conditions;
- Methods for assessing and mapping stream geomorphic conditions, and identifying and prioritizing river corridor protection and restoration projects;
- Methods for examining project feasibility and negotiating management alternatives with stakeholders; and
- Information on current programs available to Vermont landowners, towns, and other interested parties to implement river corridor protection and restoration projects.

Included in this approach is an extensive mapping exercise to lay the foundation for understanding stressors on stream channel stability at the watershed and reach scales. These maps are compiled as part of the stressor and departure analysis, and illustrate a gradient of human impacts and stream response across the watershed. The maps provide a basis for identifying projects through a step-wise procedure to screen potential projects for compatibility with long-term equilibrium conditions.

2.4.1 Stressor Analysis

The data collected through the Phase 1 and 2 SGA studies provides the basis for assessing the impacts to the hydrologic and sediment regimes, and the channel riparian and boundary conditions. This data, when combined with other watershed-scale data developed in this study, allows for the assessment of physical departure from reference conditions, and serves to validate watershed-scale patterns and stream conditions observed in the field.

Stressor, departure and sensitivity maps have been prepared to depict the effects of significant physical processes occurring within the East Branch North River study area. These maps provide an indication of where channel adjustment processes 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 channel adjustments. This is helpful in developing and prioritizing potential river corridor protection and restoration projects.

2.4.2 *Departure Analysis*

Much research has shown that alluvial river channels in wide valleys will adjust their geometry and planform to accommodate changes in the discharge and sediment loading from the upslope watershed (Dunne and Leopold, 1978). This concept was summarized by Lane (1955) to show that stream power and sediment (size and distribution) will seek a dynamic equilibrium condition in the absence of anthropogenic disturbance or catastrophic natural storm events. Slight changes from one year to another, such as variation in rainfall amounts (and a resulting variation in discharge), may cause subtle changes in channel form. However, the cross-sectional shape and profile of a river is typically stable under reference watershed conditions, and predictable given knowledge about: 1) the geologic conditions of the watershed and river corridor, 2) the topography of the watershed and river corridor, and 3) the regional climate.

Analysis of a watershed's sediment regime is a useful approach for summarizing the reach and watershed-scale stressors affecting the equilibrium conditions of river channels. Sediment regime mapping provides a context for understanding the sediment transport and channel evolution processes (Schumm, 1977) which govern changes in geometry and planform for river channels in a state of disequilibrium. The VTANR River Corridor Planning Guide (VTANR, 2010) outlines a methodology for understanding the reference and altered sediment regimes of reaches according to data collected during the Phase 2 field assessments. The sediment regime types used in this analysis are summarized below in Table 2.2.

Table 2.2: Sediment regime types for corridor planning (VTANR, 2010).

Sediment Regime	Narrative Description
Transport	Steeper bedrock and boulder/cobble cascade and step-pool stream types; typically in more confined valleys, do not supply appreciable quantities of sediments to downstream reaches on an annual basis; little or no mass wasting; storage of fine sediment is negligible due to high transport capacity derived from both the high gradient and/natural entrenchment of the channel.
Confined Source and Transport	Cobble step pool and steep plane bed streams; confining valley walls, comprised of erodible tills, glacial lacustrine, glacial fluvial, or alluvial materials; mass wasting and landslides common and may be triggered by valley rejuvenation processes; storage of coarse or fine sediment is limited due to high transport capacity derived from both the gradient and entrenchment of the channel. Look for streams in narrow valleys where dams, culverts, encroachment (roads, houses, etc.), and subsequent channel management may trigger incision, rejuvenation, and mass wasting processes.
Unconfined Source and Transport	Sand, gravel, or cobble plane bed streams; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to entrenchment or incision and associated bed form changes; these streams are not a significant sediment supply due to boundary resistance such as bank armoring, but may begin to experience erosion and supply both coarse and fine sediment when bank failure lead to channel widening; storage of coarse or fine sediment is negligible due to high transport capacity derived from the deep incision and little or no floodplain access. Look for straightened, incised or entrenched streams in unconfined valleys, which may have been bermed and extensively armored and are in Stage II or early Stage III of channel evolution.

Table 2.2: Sediment regime types for corridor planning (VTANR, 2010).

Sediment Regime	Narrative Description
Fine Source and Transport & Coarse Deposition	Sand, gravel, or cobble streams with variable bed forms; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to vertical profile and associated bed form changes; these streams supply both coarse and fine sediments due to little or no boundary resistance; storage of fine sediment is lost or severely limited as a result of channel incision and little or no floodplain access; an increase in coarse sediment storage occurs due to a high coarse sediment load coupled with the lower transport capacity that results from a lower gradient and/or channel depth. Look for historically straightened, incised, or entrenched streams in unconfined valleys, having little or no boundary resistance, increased bank erosion, and large unvegetated bars. These streams are typically in late Stage III and Stage IV of channel evolution.
Coarse Equilibrium (in = out) & Fine Deposition	Sand, gravel, or cobble streams with equilibrium bedforms; at least one side of the channel is unconfined by valley walls; these streams transport and deposit coarse sediment in equilibrium (stream power—produced as a result of channel gradient and hydraulic radius—is balanced by the sediment load, sediment size, and channel boundary resistance); and store a relatively large volume of fine sediment due to the access of high frequency (annual) floods to the floodplain. Look for unconfined streams, which are not incised or entrenched, have boundary resistance (woody buffers), minimal bank erosion, and vegetated bars. These streams are Stage I, late IV, and Stage V.
Deposition	Silt, sand, gravel, or cobble streams with variable and braided bed forms; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to changes in slope and/or depth resulting in the predominance of transient depositional features; storage of fine and coarse sediment frequently exceeds transport**. Floodplains are accessed during high frequency (annual) floods. Look for unconfined streams, which are not incised or entrenched, have become significantly over-widened, and if high rates of bank erosion are present, it is offset by the vertical growth of unvegetated bars. These regimes may be located at zones of naturally high deposition (e.g., active alluvial fans, deltas, or upstream of bedrock controls), or may exist due to impoundment and other backwater conditions above weirs, dams, and other constrictions.

** Use of the "Deposition" regime characterization may be rare, but valuable as a planning tool, where the reach is storing far more than it is transporting during some defined planning period. The extreme example would be that of an impounded reach where all of the coarse and a great percentage of the fine sediments are being deposited, rather than transported downstream. This man-made condition may change, thereby changing the sediment regime, but is not likely over the period at which the corridor plan will be used.

Channel evolution models (CEM) also provide a basis for understanding the temporal scale of channel adjustments and departure in the context of SGA Phase 2 results. Both the "D" stage and "F" stage CEMs (VTDEC, 2009) are helpful for explaining the channel adjustment processes underway in the East Branch North River watershed. The "F" stage CEM is used to understand the process that occurs when a stream degrades (incises) its bed. The more dominant adjustment process for the "D" stage channel evolution is aggradation, widening and planform change. D-stage CEM typically occurs where grade controls prevent severe channel incision and abandonment of the adjacent floodplain. The common stages of both CEMs are depicted in Figure 2.1 below.

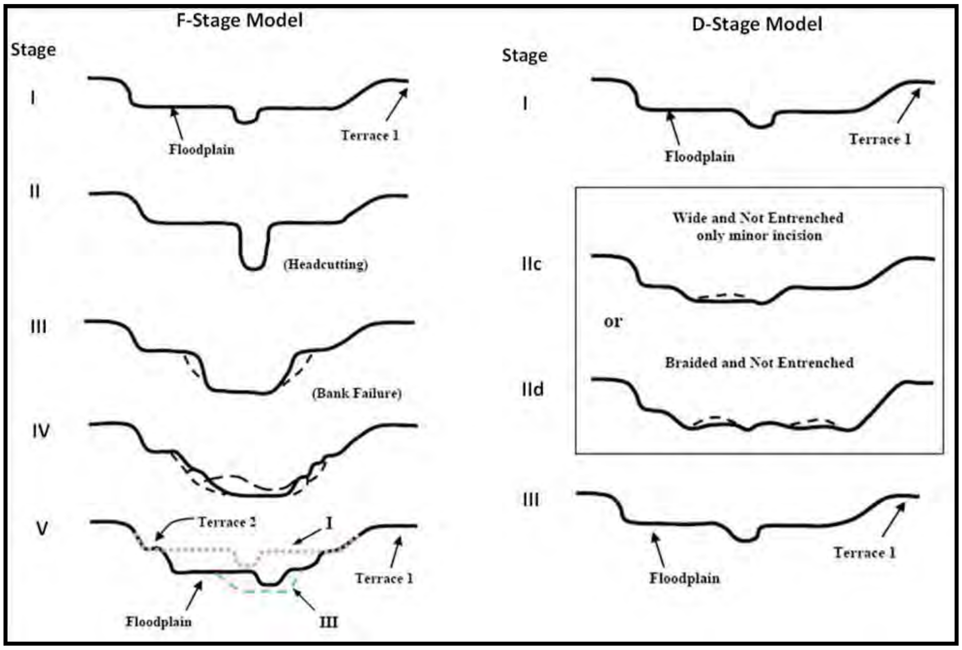


Figure 2.1: Typical channel evolution models for F-stage and D-stage (VTDEC, 2009).

2.4.3 Sensitivity Analysis

The following description of the sensitivity of various stream types to changes in sediment and flow regimes, boundary conditions and channel morphology, is included from the most recent version of the VTANR River Corridor Planning Guide (VTANR, 2010).

> Certain geomorphic stream types are inherently more sensitive than others, responding readily through lateral and/or vertical adjustments to high flow events and/or influxes of sediment. Other geomorphic stream types may undergo far less adjustment in response to the same watershed inputs. In general, streams receiving a large supply of sediment, having a limited capacity to transport that sediment, and flowing through finer-grained, non-cohesive materials are inherently more sensitive to adjustment and likely to experience channel evolution processes more rapidly than streams with a lower sediment supply, higher transport capacity and flowing through cohesive or coarse-grained materials (Montgomery and Buffington, 1997). The geometry and roughness of the stream channel and floodplain (i.e., the width, depth, slope, sediment sizes, and floodplain relations) dictate the velocity of flow, how much erosive power is produced, and whether the stream has the power to transport the sediment delivered from upstream (Leopold, 1994). If the energy produced by the depth and slope of the water is either too little or too great in relation to the sediment available for transport, the stream may be out of equilibrium and channel adjustments are likely to occur, especially during flood conditions (Lane, 1955).

Stream sensitivity maps have been prepared for the East Branch North River study area. Sensitivity ratings were assigned using the VTDEC Protocols (VTDEC, 2009).

2.5 Project Identification

Site-specific projects were identified using methods outlined by VTANR in Chapter 6 Preliminary Project Identification and Prioritization (VTANR, 2010). This planning guide is intended to aid in the development of projects that protect and restore river equilibrium conditions. The projects identified for the study reaches 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 toward a state of geomorphic equilibrium through active, physical alteration of the channel and/or floodplain. Often this approach involves the removal of human constructed constraints or the construction of meanders, floodplains or stable banks. Riparian buffer re-vegetation and long-term protection of a river corridor is essential to this alternative

Passive Geomorphic Restoration allows rivers to return toward 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 ideal results. Riparian buffer re-vegetation and long-term protection of a river corridor (e.g., corridor easements) is essential to this alternative.

Conservation is an option to consider when stream conditions are generally "good" or "reference" and the channel is in a state of dynamic equilibrium. Typically, conservation is applied to minimally disturbed reaches where river structure and function and vegetation associations are relatively intact, and/or where high quality aquatic habitat is found.

Infrastructure Resiliency are projects designed to reduce fluvial erosion and inundation hazards to adjacent municipal and private infrastructure. These projects typically prioritize infrastructure protection over channel stability and aquatic habitat.

3.0 Phase 1 Results

3.1 Reach Delineations

The 16.04 miles of surface waters within the East Branch North River watershed were divided into 15 reaches during the SGAT analysis carried out by VTANR and FEA. Reach divisions were based on changes in valley geometry, channel slope, and the size and influence of tributaries entering the mainstem channel. The East Branch North River mainstem and two tributaries, Branch Brook and Hager Brook, were included in the SGAT analysis. Table 3.1 summarizes data for the study watersheds. Detailed information about each reach location is found in the reach reports in Appendix A.

Table 3.1: Tributary and sub-tributary summary data.

DMS ID	Name	Watershed Area (square miles)	Assessed River Length (mi)	Number of Assessed Reaches
M01	East Branch North River	39.54	9.14	8
T1	Branch Brook	9.58	4.1	4
T2	Hager Brook	3.70	2.8	3

3.2 Reference Stream Types

Windshield survey measurements and observations, as well as remotely collected data of valley confinement, channel slope, and sinuosity, were used to develop reference stream types for the assessed reaches according to the Rosgen (1994) and Montgomery and Buffington (1997) classification systems. Characterization of reference stream types is based on the channel forms and processes we would expect in a particular geologic and geomorphic setting without human influences. Detailed information about each reach reference stream type is found in the reach reports in Appendix A. Table 3.2 presents general valley and channel characteristics associated with reference stream types found in the East Branch North River watershed. Table 3.3 describes the reference stream conditions for each study reach.

Table 3.2: Reference stream type characteristics.

Stream Type	Valley Confinement	Channel Slope	Sinuosity	Bedform	Number of Study Reaches*
A	Confined	> 4%	Low	Cascade or Step-pool	1 (7%)
B	Confined (Typically)	2 – 4%	Low	Step-pool or Plane bed	6 (40%)
C	Unconfined	< 2%	Moderate	Riffle Pool	7 (46%)
E	Unconfined	<2%	Highly	Dune Ripple	1 (7%)

* Number of reaches and percentage of total reaches represented by type.

Table 3.3: Reach and watershed characteristics.

Surface Water	Reach ID	Watershed Area (Mi^2)	Channel Length (Mi)	Channel Width (ft)	Channel Slope (%)	Sinuosity	Valley Type*	Reference Stream Type†	Bedform‡
East Branch North River	M01	39.54	1.64	66.1	1.42	1.01	SC	B	Riffle-Pool
	M02	35.23	1.28	62.8	1.08	1.07	NW	C	Riffle-Pool
	M03	23.06	1.52	52.1	1.87	1.14	NW	C	Riffle-Pool
	M04	20.28	0.86	49.3	0.72	1.03	BD	C	Riffle-Pool
	M05	14.83	1.62	42.9	1.29	1.05	BD	C	Riffle-Pool
	M06	9.65	1.18	35.5	1.46	1.00	VB	C	Riffle-Pool
	M07	1.48	0.36	15.6	3.16	1.01	VB	C	Riffle-Pool
	M08	1.28	0.68	14.6	5.05	1.00	SC	A	Step-Pool
Branch Brook	T1.01	9.58	0.65	35.4	1.67	1.02	NW	B	Riffle-Pool
	T1.02	7.76	1.24	32.3	1.92	1.00	NW	B	Riffle-Pool
	T1.03	6.50	1.13	29.8	1.37	1.14	VB	C	Riffle-Pool
	T1.04	3.42	1.08	22.5	2.13	1.03	NW	B	Step-Pool
Hager Brook	T2.01	3.70	1.36	23.3	4.32	1.04	SC	B	Step-Pool
	T2.02	2.20	0.76	18.5	2.22	1.00	NW	B	Riffle-Pool
	T2.03	1.75	0.65	16.8	1.28	1.24	VB	E	Riffle-Pool

* NC= Narrowly-confined; SC= Semi-confined; NW= Narrow; BD=Broad; VB=Very Broad
† per Rosgen (1994)
‡ per Montgomery and Buffington (1997)

Figure 3.1 presents the location of the reference stream types developed for the East Branch North River watershed. C-type reaches are the most common (46%) within the study area under reference conditions. C-type streams are typically characterized by a moderately sinuous channel found in a broad, unconfined valley setting with a balance between the upslope sediment supply and the transport capacity. B-type streams represent 40% of the study area and are typically characterized by a low to moderately sinuous channel located within a confined valley that is dominated by sediment transport processes. The study reaches included one A-type reach (7%) which are typically found in the steep headwater areas and one E-type reach (7%) which are typically found in broad valleys with low slope and depositional environments. Outside of the headwater areas; channel slope is relatively consistent through most of the study area, therefore reference stream type is primarily influenced by confinement. C-type reaches typically have broad and very broad confinement, and B-type reaches are typically found in semi-confined or narrow valleys.

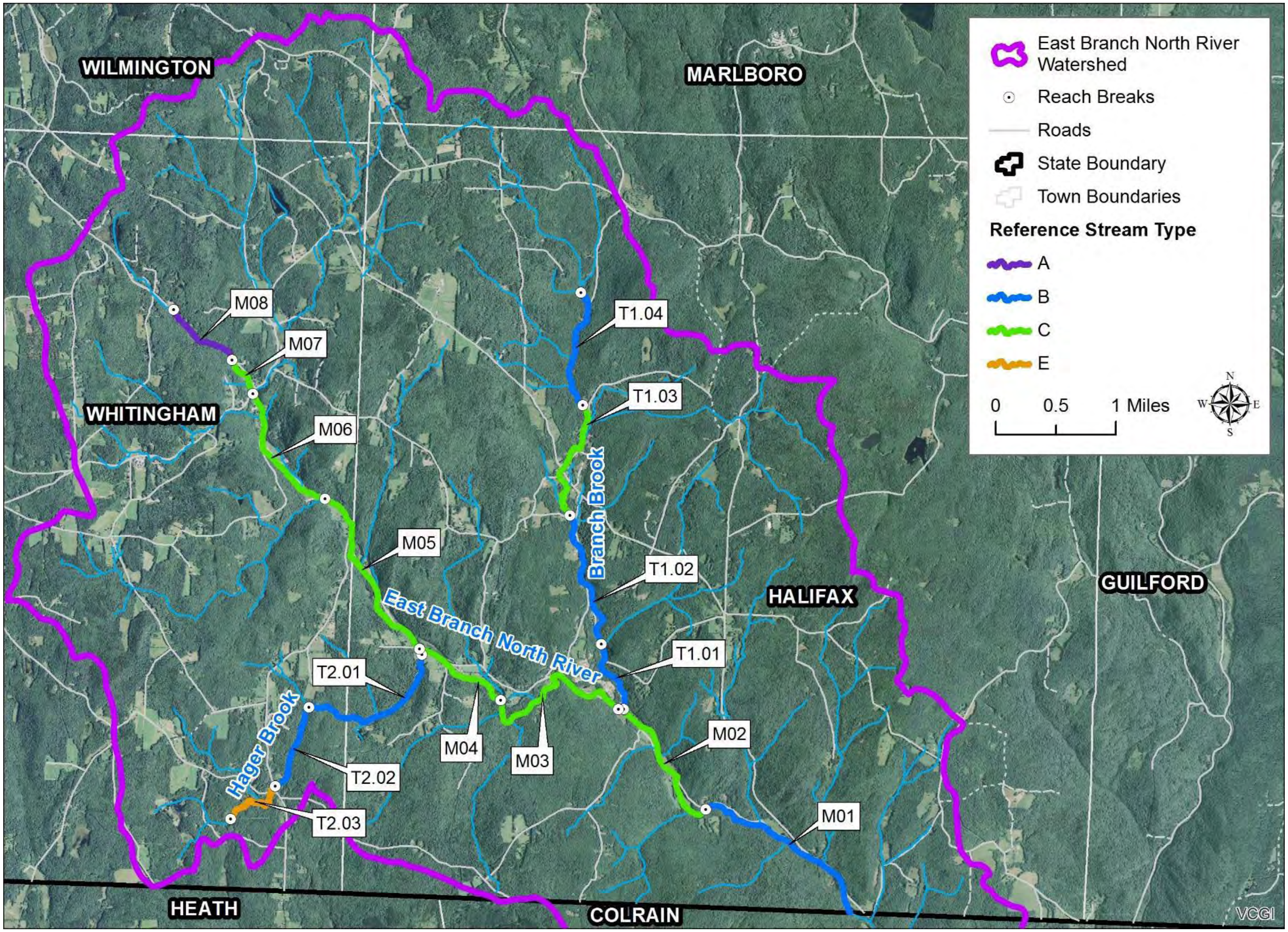


Figure 3.1: Reference stream types per Rosgen (1994) for the East Branch North River watershed.

3.3 Phase 1 Impacts Summary

Based on the Phase 1 impact scores, the DMS also develops predictions for channel adjustment processes (VTDEC, 2009). These predictions are based on the dominant impacts recorded for each reach, and are categorized based on the impacts typically associated with the following four channel adjustment processes: 1) Degradation (e.g., channel incision); 2) Aggradation (e.g., increased sediment deposition); 3) Channel widening (e.g., increased bank erosion); 4) Planform Changes (e.g., irregular meander patterns) (Table 3.4 and Figure 3.2). Impacts are scored from 0-2 (Insignificant to Major) and the total score (0-32) is indicative of the total degree of impact, however there are no qualitative ratings assigned to a particular Phase 1 impact score.

Table 3.4: Final Impact Score Parameters for Phase 1 Dataset.

Phase 1 Step	Phase 1 Parameter	Impact Category
4.1	Local Watershed Land Cover/Land Use	Land Use
4.2	Corridor Watershed Land Cover/Land Use	
4.3	Riparian Buffer Width	
5.1	Flow Regulations	Channel Modifications
5.2	Bridges and Culverts	
5.3	Bank Armoring	
5.4	Channel Straightening	
5.5	Dredging and Gravel Mining	
6.1	River Corridor Encroachments	Floodplain Modifications and Planform Changes
6.2	River Corridor Development	
6.3	Depositional Features	
6.4	Meander Migration	
6.5	Meander Belt Width Departure	
6.6	Meander Wavelength Departure	
7.2	Bank Erosion	Bed and Bank Conditions
7.3	Debris and Ice Jam Potential	

In the East Branch North River watershed, the most pervasive impacts mapped during Phase 1 assessment were river corridor and floodplain encroachments (Figure 3.3), and riparian buffer degradation (Figure 3.4). These are commonly the most widespread impacts in rural Vermont watersheds due to the presence of roadways along river networks and development and agricultural land uses found along the flat river valleys. Using the channel adjustment process ratings, a provisional geomorphic rating is developed for each reach based on the methods outlined in the SGA Phase 1 protocols (VTDEC, 2009). Table 3.5 outlines the four possible geomorphic ratings based on the SGA methods, and Figure 3.5 presents the provisional geomorphic condition for all study reaches.

Table 3.5: SGA Reach Condition Ratings.

SGA Rating	Predicted Conditions and Processes
Reference	In Equilibrium – no apparent or significant channel, floodplain, or land cover modifications; channel geometry is likely to be in balance with the flow and sediment produced in its watershed.
Good	In Equilibrium but may be in transition into or out of the range of natural variability – minor erosion or lateral adjustment but adequate floodplain function; any adjustment from historic modifications nearly complete.
Fair	In Adjustment – moderate loss of floodplain function; or moderate to major planform adjustments that could lead to channel avulsions.
Poor	In Adjustment and Stream Type Departure - may have changed to a new stream type or central tendency of fluvial processes – significant channel and floodplain modifications may have altered the channel geometry such that the stream is not in balance with the flow and sediment produced in its watershed.

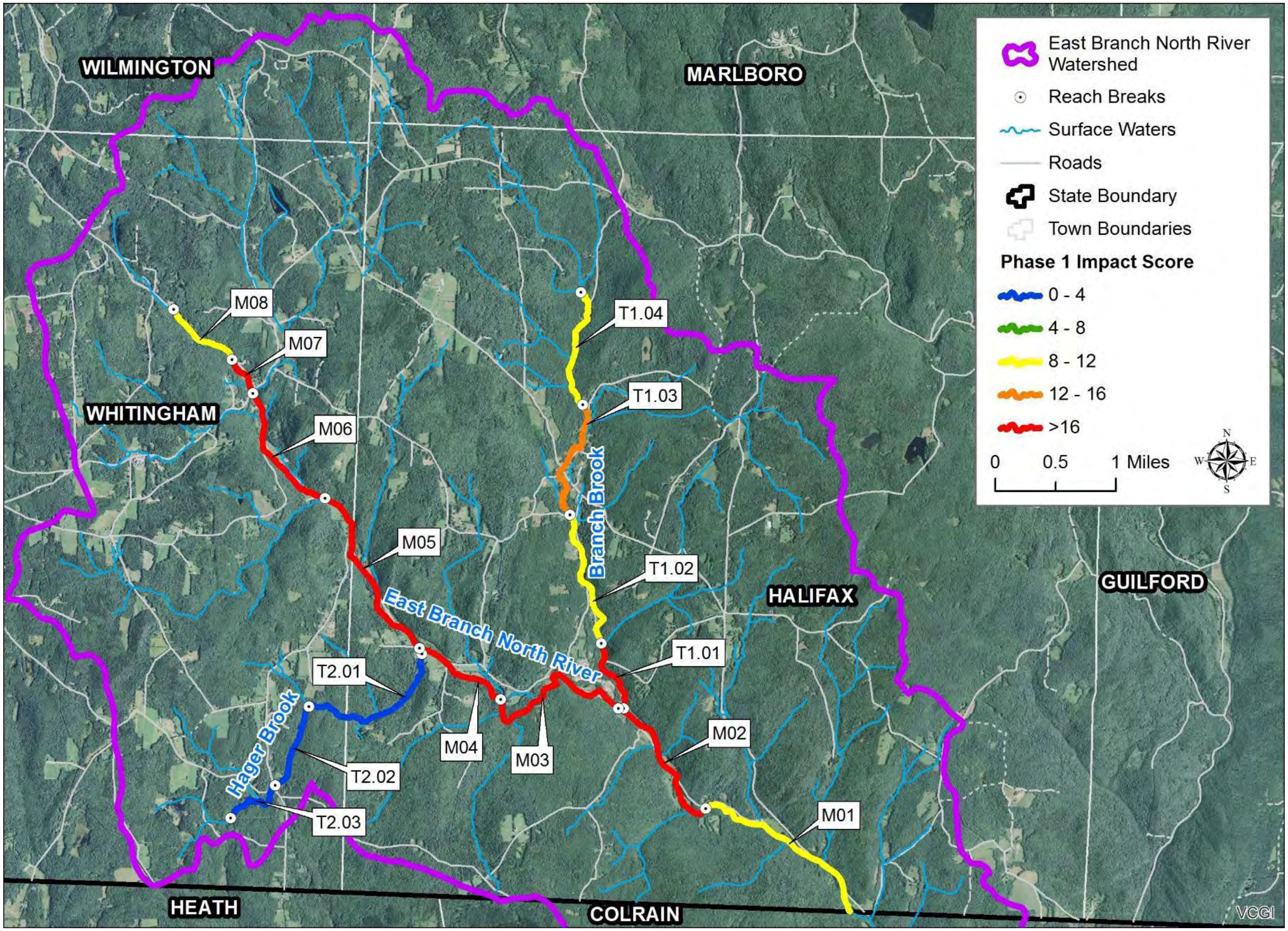


Figure 3.2: Phase 1 impact scores for the East Branch North River watershed.

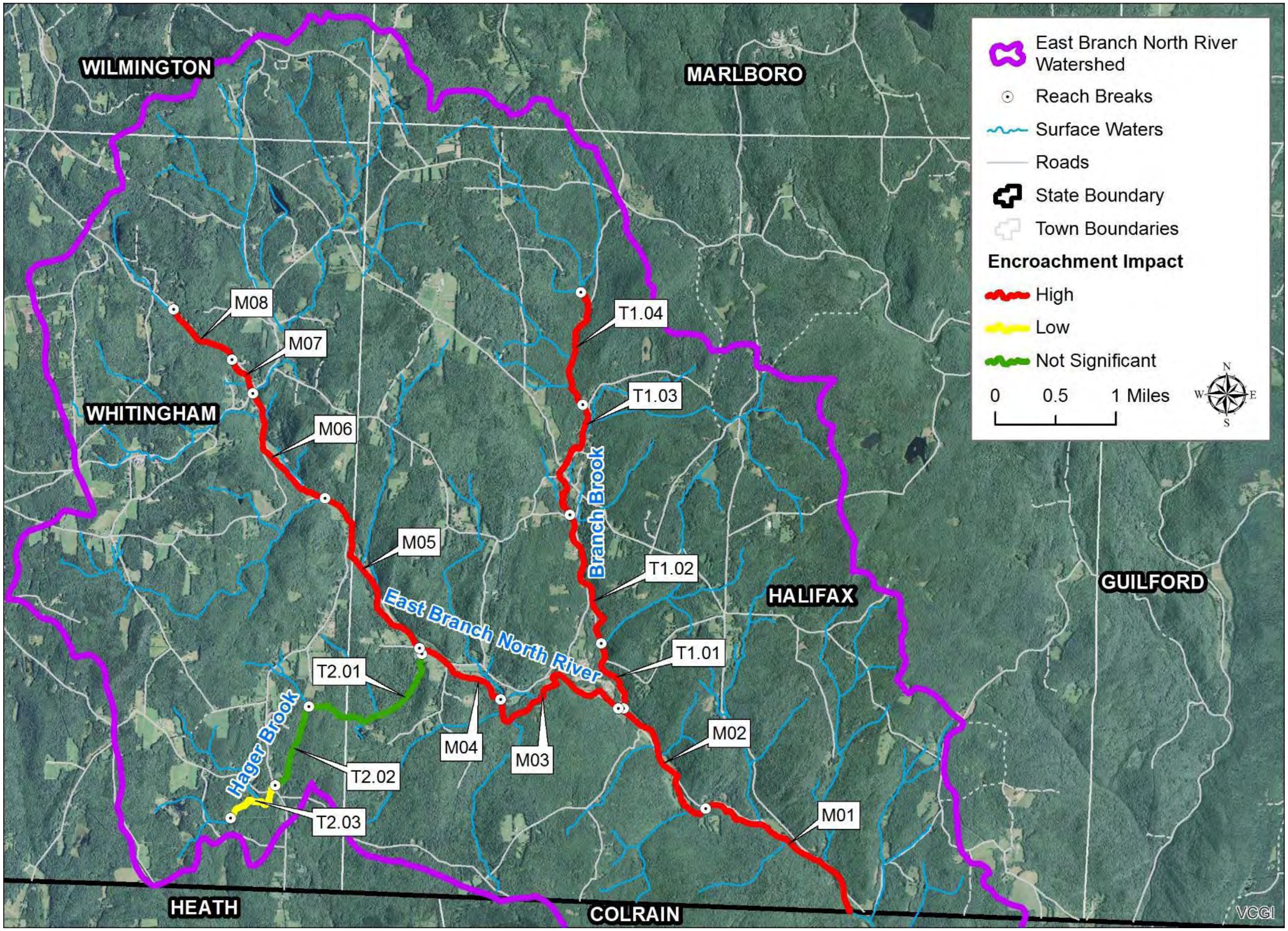


Figure 3.3: Phase 1 encroachment impacts for the East Branch North River watershed.

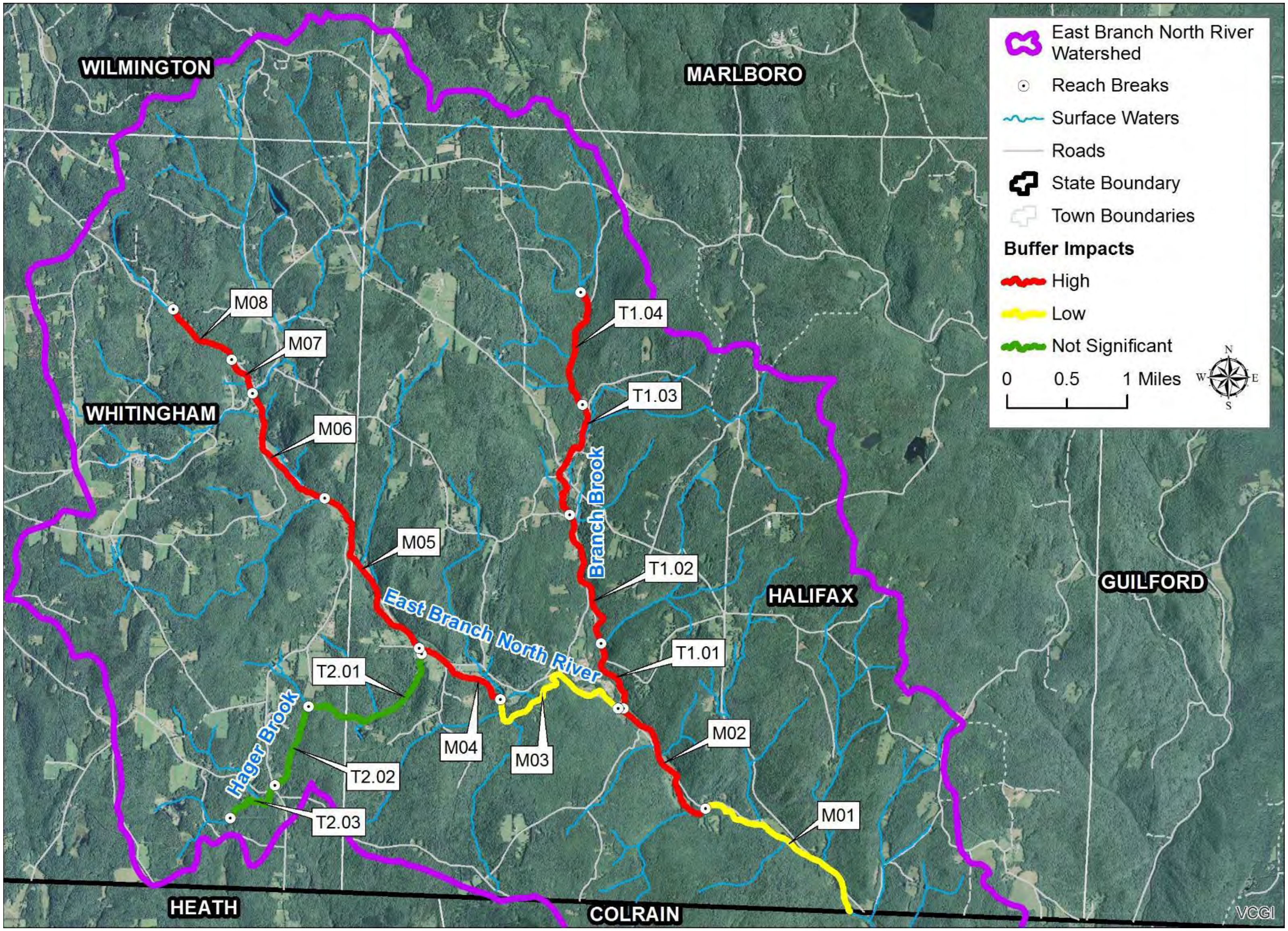


Figure 3.4: Phase 1 buffer impacts for the East Branch North River watershed.

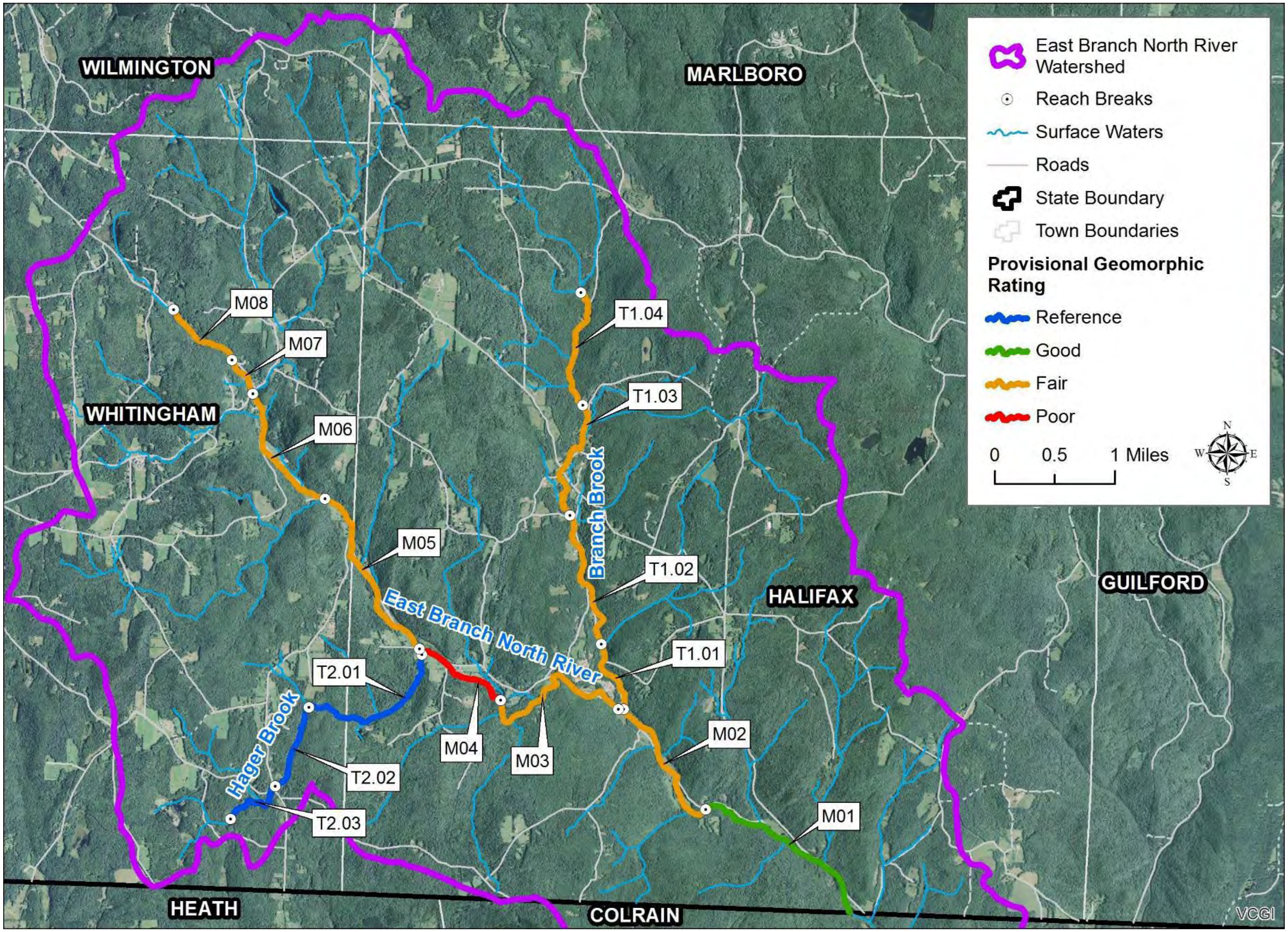


Figure 3.5: Provisional geomorphic ratings for the East Branch North River watershed.

3.4 Phase 2 Reach Recommendations

Using the Phase 1 Impact Ratings as the primary basis for reach selection, a list of reaches was developed for Phase 2 surveys within the East Branch North River and Branch Brook watersheds. Table 3.6 summarizes the eight (8) selected reaches covering 8.7 miles based on watershed location, channel length, channel slope, valley type, and preliminary reference stream type.

Table 3.6: Phase 2 reach recommendations and Phase 1 Impact Ratings.

Surface Water	Reach ID	Channel Length (Mi)	Channel Slope (%)	Valley Type*	Reference Stream Type†	Bedform‡	Impact Score (Geo Condition)
East Branch North River	M02	1.28	1.08	NW	C4	Riffle-Pool	19 (Poor)
	M03	1.52	1.87	NW	C3	Riffle-Pool	18 (Poor)
	M04	0.86	0.72	BD	C4	Riffle-Pool	22 (Poor)
	M05	1.62	1.29	BD	C4	Riffle-Pool	18 (Poor)
	M06	1.18	1.46	VB	C3	Riffle-Pool	20 (Poor)
	M07	0.36	3.16	VB	$C3_b$	Riffle-Pool	18 (Poor)
Branch Brook	T1.01	0.65	1.67	NW	$B3_c$	Riffle-Pool	17 (Poor)
	T1.02	1.24	1.92	NW	$B3_c$	Riffle-Pool	14 (Fair)

* SC= Semi-confined; NW= Narrow; BD=Broad; VB=Very Broad, NC=No Confinement; † per Rosgen, 1994
‡ per Montgomery and Buffington, 1997; Δ denotes that the uppermost segment of each reach was not planned for Phase 2 assessment

4.0 Phase 2 Results and River Corridor Planning

Phase 2 assessments were conducted on 8 reaches in October and November, 2016. Reaches M03, M04, M06, and M07 were segmented during the Phase 2 data collection, for a total of 13 reaches and segments covering 8.7 miles (Figures 4.1 - 4.2). Two (2) segments were not fully assessed due to a bedrock gorge (M03.B) and numerous beaver impoundments (M04.A).

4.1 Phase 2 Segment Summary Sheets

One page summaries for each Phase 2 segment/reach are presented in this section. The impact summary section includes color-coded designations of Not Significant, Low, or High levels of impact based on data collected during the Phase 2 assessments. Impact levels were assigned based on the longitudinal effect (<5% - Not Significant, 5-20% - Low, and >20% - High), and the overall impact of discrete features on the reach/segment (constrictions, stormwater inputs, steep riffles, etc.). Based on our professional judgment; potential impacts for bridges (B), culverts (C), and other (O) constrictions were summarized with the following abbreviations:

- AOP: Aquatic organism passage
- D: Deposition upstream and/or downstream
- E: Bank erosion upstream and/or downstream
- I: Ice/Debris jamming
- R/R: Failing bank armor upstream and/or downstream
- S: Scour upstream and/or downstream

Incision Ratio and Entrenchment Ratios are important indicators of the degree of stream departure from reference condition. Incision ratio describes the degree of floodplain accessibility: values close to 1.0 represent reference conditions with an accessible floodplain, values greater than 2.0 indicate an extreme disconnection of floodplain typically associated with a stream type departure. Entrenchment ratio describes the width of the floodprone area in relation to the bankfull channel width. Reference entrenchment ratios vary with stream type and valley setting. Stream impacts such as encroachment, incision, widening, and straightening may all lower the entrenchment ratio. C-type streams typically have entrenchment ratios greater than 2.0 and values below 2.0 or 1.4 represent stream type departures to B or F-type respectively. Definitions for technical terminology within the summary sheets are provided in the Glossary of Terms in Section 8.0.

Habitat assessment rankings for large woody debris and pool counts (measured in reference to predicted bankfull width - wbkf) are defined in Table 4.1.

Table 4.1: LWD and Pool Ranking for RHA.

Rank	LWD		Pool	
	Diameter (ft)	Length (relative to wbkf)	Depth (ft)	Length/Width (relative to wbkf)
1	0.5≤D<1.0	<0.5	1.0≤D<2.0	<0.5
2	0.5≤D<1.0	≥0.5	1.0≤D<2.0	≥0.5
3	1.0≤D<2.0	<0.5	2.0≤D<3.0	<0.5
4	1.0≤D<2.0	≥0.5	2.0≤D<3.0	≥0.5
5	D≥2.0	<0.5	D≥3.0	<0.5
6	D≥2.0	≥0.5	D≥3.0	≥0.5
7	--	--	D≥3.0	≥1.0

4.1.1 Halifax, VT Phase 2 Assessment Summary

The Phase 2 assessed reaches/segments on East Branch of the North River and Branch Brook within the Town of Halifax are described below (Figure 4.1). Reach M03.B was not assessed due to continuous bedrock grade control and reach M04.A was not assessed due to numerous beaver impoundments.

- Reach M02
    - This reach flows from the confluence with Branch Brook to just downstream of the confluence with Randall Brook. Historic straightening and armoring along VT 112 caused channel incision that appears to be slowing, with widening increasing in some areas.
- Reach M03
    - Reach M03 was divided into three segments based on grade controls. The first segment (A) flows from the downstream extent of the gorge to the confluence with Branch Brook and is characterized by channel incision due to historic straightening and armoring along VT 112. Segment B is relatively stable due to a continuous bedrock gorge including Halifax Falls. Segment C flows from the downstream extent of an area with high beaver activity to the gorge.
- Reach M04
    - Reach M04 was divided into two segments based on beaver activity. The first segment (A) had numerous beaver dams. Segment B flows from the confluence with Hager Brook to the upstream end of the area with higher beaver activity. This reach was characterized by channel incision that appears to be slowing, with widening increasing in some areas.
- Reach M05
    - This reach begins near the intersection of Sprague Brook Road and VT 112 and flows to the confluence with Hager Brook and is characterized by incision due to historic straightening and armoring along VT 112
- Reaches T1.01 and T1.02
    - Reach T1.01 begins at the confluence of Sperry Brook and Branch Brook and flows to the confluence of Branch Brook and the East Branch of the North River. Reach T1.02 begins just upstream of the Sprague Road crossing and flows to the confluence with Sperry Brook. Both reaches are characterized by incision due to historic straightening and armoring along Branch Road.

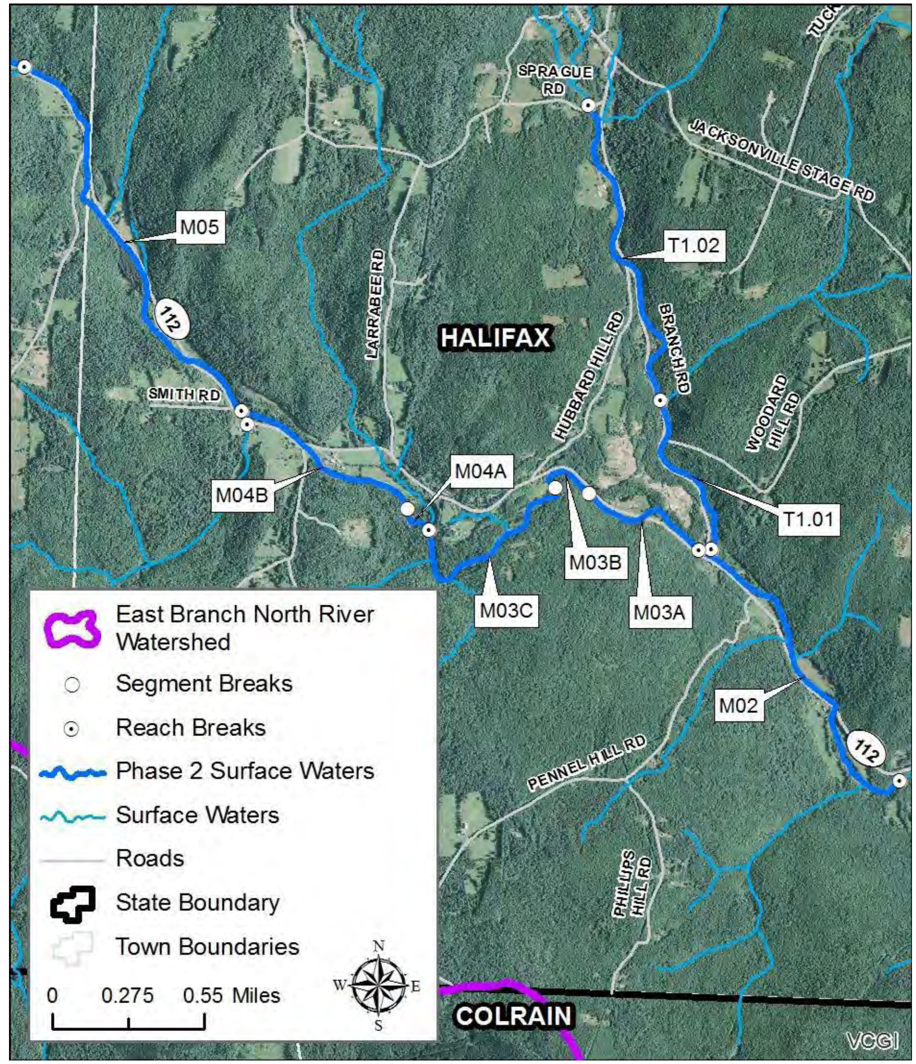


Figure 4.1: Halifax, VT reach and segment locations.

Stream: North River	Reach: M02	Town: Halifax	Date Assessed: 10/19/16
Channel Length (ft): 6,737	Channel Slope (%): 1.08	Sinuosity: 1.07	Watershed Area (mi^2): 35.23

Stream Type Summary

	P1 Reference	P2 Assessed
Confinement	Narrow	Narrow
Bedform	Riffle-Pool	Riffle-Pool
Median Substrate	Gravel	Cobble
Stream Type	C	F

Ph2 Cross-Section Data

Curve Width (ft)	62.8
Bankfull Width (ft)	71.9
Max Depth (ft)	2.6
Width/Depth Ratio	42.1
Entrenchment Ratio	1.3
Incision Ratio	2.3

Crossing/Constriction Summary

Type	Location	% wbkf	Impacts
B	State	96%	D,E
B	Town	56%	D,S

# of Other Constrictions: 0
# of Grade Controls: 2

Rapid Habitat Assessment

Rank	LWD	Pools
1	12	0
2	7	1
3	2	4
4	4	1
5	0	0
6	0	1
7	0	2
#/mile	19	7

Number of Debris Jams: 0

Step 6/7 Summary

RHA Score/Condition	86/Fair
Habitat Type Departure	None
RGA Score / Condition	32/Fair
Dominant Adjustment	Degradation
CEM Model Stage	F/II
Stream Type Departure	C to F
Stream Sensitivity	Extreme

Impact Summary

Bank Erosion	Stormwater
Armoring	Constrictions
Riparian Buffer	Deposition
Encroachment	Migration
Development	Steep Riffle
Corridor Land Use	Head Cut
Mass Failure	Straightening
Flow Regulation	Dredging

Potential Projects in Reach

- NR-1: Buffer Planting and Corridor Protection – Plant woody vegetation to stabilize a large eroding bank and protect this area and an important floodplain from future development.
- NR-2: Corridor Protection – Protect the floodplain immediately downstream of the Branch Brook confluence where an alluvial fan exists.
- NR-3: Bridge Retrofit/Replacement – Consider replacing the Branch Road bridge or moving the abutments to increase bankfull width.

Reach Highlights: Historically this reach was incised due to straightening and encroachment along VT 112. A large alluvial fan is located in the upper portion of the reach, downstream of the confluence with Branch Brook. We assessed this reach as Stage II due to channel incision, but widening in some areas suggests it may be transitioning into a stage III reach. The stream departed from a C to a F-type channel due to incision and entrenchment.

Historically incised and straightened F-type channel.

Alluvial fan deposits in the upper portion of the reach.

Stream: North River	Reach: M03.A	Town: Halifax	Date Assessed: 10/19/16
Channel Length (ft): 2,262	Channel Slope (%): 1.87	Sinuosity: 1.14	Watershed Area (mi^2): 23.06

Stream Type Summary

	P1 Reference	P2 Assessed
Confinement	Narrow	Semi Confined
Bedform	Riffle-Pool	Riffle-Pool
Median Substrate	Cobble	Cobble
Stream Type	B_c	B_c

Ph2 Cross-Section Data

Curve Width (ft)	52.1
Bankfull Width (ft)	63
Max Depth (ft)	2.9
Width/Depth Ratio	38.4
Entrenchment Ratio	1.5
Incision Ratio	2.0

Crossing/Constriction Summary

Type	Location	% wbkf	Impacts
B	State	115%	D

# of Other Constrictions: 0
# of Grade Controls: 2

Rapid Habitat Assessment

Rank	LWD	Pools
1	2	4
2	4	1
3	0	0
4	0	0
5	0	0
6	0	0
7	0	2
#/mile	11	13

Number of Debris Jams: 1

Step 6/7 Summary

RHA Score/Condition	76/Fair
Habitat Type Departure	None
RGA Score / Condition	35/Fair
Dominant Adjustment	Degradation
CEM Model Stage	F/III
Stream Type Departure	None
Stream Sensitivity	High

Impact Summary

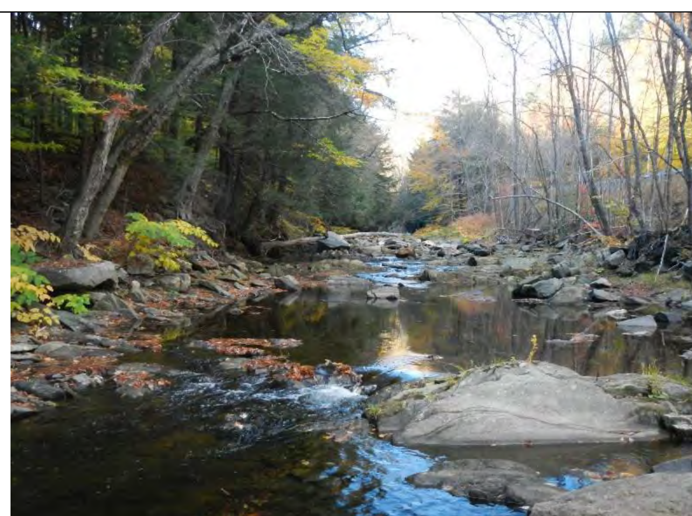
Bank Erosion	Stormwater
Armoring	Constrictions
Riparian Buffer	Deposition
Encroachment	Migration
Development	Steep Riffle
Corridor Land Use	Head Cut
Mass Failure	Straightening
Flow Regulation	Dredging

Potential Projects in Reach

- No Projects in Segment

Reach Highlights: Historically this segment was incised due to historic straightening and encroachment along Rt 112. Moderate bank scour and bankfull widths typically greater than the predicted curve width indicate that the reach may be widening. Further incision is also unlikely due to grade control and large substrate. We assessed the reach as early Stage III with limited potential for further widening or planform adjustment due to the road encroachment.

Historically straightened and incised F-type channel.



Grade controls in the upper portion of the segment, approaching a bedrock gorge.

Stream: North River	Reach: M03.C	Town: Halifax	Date Assessed: 10/19/16
Channel Length (ft): 4,116	Channel Slope (%): 1.87	Sinuosity: 1.14	Watershed Area (mi^2): 23.06

Stream Type Summary

	P1 Reference	**P2 Assessed**
Confinement	Broad	Broad
Bedform	Riffle-Pool	Riffle-Pool
Median Substrate	Cobble	Cobble
Stream Type	C	C

Ph2 Cross-Section Data

Curve Width (ft)	52.1
Bankfull Width (ft)	45
Max Depth (ft)	2.4
Width/Depth Ratio	25.6
Entrenchment Ratio	2.9
Incision Ratio	1.4

Crossing/Constriction Summary

Type	Location	% wbkf	Impacts
B	Private	58%	D

# of Other Constrictions: 0
# of Grade Controls: 4

Rapid Habitat Assessment

Rank	LWD	Pools
1	0	2
2	9	2
3	1	1
4	5	1
5	0	0
6	1	1
7	0	2
#/mile	20	11

Number of Debris Jams: 0

Step 6/7 Summary

RHA Score/Condition	103/Fair
Habitat Type Departure	None
RGA Score / Condition	48/Fair
Dominant Adjustment	Planform
CEM Model Stage	F/IV
Stream Type Departure	None
Stream Sensitivity	High

Impact Summary

Bank Erosion	Stormwater
Armoring	Constrictions
Riparian Buffer	Deposition
Encroachment	Migration
Development	Steep Riffle
Corridor Land Use	Head Cut
Mass Failure	Straightening
Flow Regulation	Dredging

Potential Projects in Reach

- NR-5: Stormwater Treatment and Gully Stabilization – Concentrated runoff from an active subdivision site is exacerbating gully erosion and a mass failure, implement stormwater treatment practices to reduce concentrated runoff and stabilize the gully.
- NR-6: Corridor Protection: Protect an important forested floodplain from future development.

Reach Highlights: This segment is set back from VT 112 upstream of Halifax Falls and therefore was less incised due to encroachment and armoring than nearby reaches and remains a C-type channel. Within the broad valley, the channel maintains the ability to move and access large floodplains. We assessed this segment as Stage IV due to the presence of multiple large flood chutes and evidence of aggradation occurring in some areas.

C-type channel with floodplain access.

Large flood chute.

Stream: North River	Reach: M04.B	Town: Halifax	Date Assessed: 10/20/16
Channel Length (ft): 4,032	Channel Slope (%): 0.72	Sinuosity: 1.03	Watershed Area (mi^2): 20.28

Stream Type Summary

	P1 Reference	P2 Assessed
Confinement	Broad	Semi Confined
Bedform	Riffle-Pool	Riffle-Pool
Median Substrate	Gravel	Gravel
Stream Type	C	F

Ph2 Cross-Section Data

Curve Width (ft)	49.3
Bankfull Width (ft)	55
Max Depth (ft)	2.2
Width/Depth Ratio	31.6
Entrenchment Ratio	1.1
Incision Ratio	2.0

Crossing/Constriction Summary

Type	Location	% wbkf	Impacts
B	State	97%	D

# of Other Constrictions: 0
# of Grade Controls: 0

Rapid Habitat Assessment

Rank	LWD	Pools
1	5	4
2	9	7
3	2	0
4	4	2
5	0	0
6	0	0
7	0	0
#/mile	26	17

Number of Debris Jams: 2

Step 6/7 Summary

RHA Score/Condition	82/Fair
Habitat Type Departure	None
RGA Score / Condition	35/Fair
Dominant Adjustment	Degradation
CEM Model Stage	F/II
Stream Type Departure	C to F
Stream Sensitivity	Extreme

Impact Summary

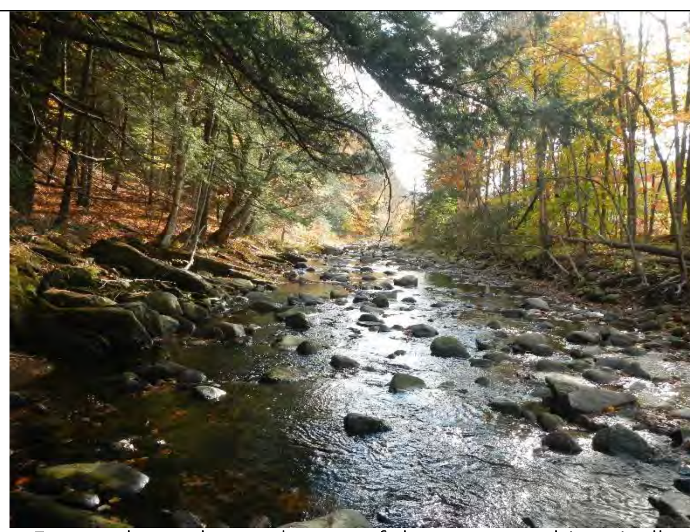
Bank Erosion	Stormwater
Armoring	Constrictions
Riparian Buffer	Deposition
Encroachment	Migration
Development	Steep Riffle
Corridor Land Use	Head Cut
Mass Failure	Straightening
Flow Regulation	Dredging

Potential Projects in Reach

- NR-7: Corridor Protection – Protect two important floodplain areas totally more than 5 acres from future development.
- NR-8: Buffer Planting – Establish a woody buffer along approximately 500ft of bank.
- NR-9: Berm Removal and Buffer Planting – Post-Irene channel dredging and berming has filled a long floodplain bench and the spoils are densely vegetated with Japanese Knotweed, remove the spoils and plant with native woody vegetation.

Reach Highlights: Historically this segment was incised due to straightening, armoring and encroachment along VT 112, which caused a stream type departure from a C to a F-type channel. We observed evidence of ongoing aggradation and recent widening. We assessed the segment as recently transitioning to Stage III, however widening and planform adjustment potential is limited due to road encroachment.


Segment upstream of beaver activity, with evidence of historic incision.


F-type channel near the top of the segment, historically incised due to straightening and encroachment.

Stream: North River	Reach: M05	Town: Halifax/Whitingham	Date Assessed: 11/07/16
Channel Length (ft): 8,550	Channel Slope (%): 1.29	Sinuosity: 1.05	Watershed Area (mi²): 14.83

Stream Type Summary

	P1 Reference	P2 Assessed
Confinement	Broad	Broad
Bedform	Riffle-Pool	Riffle-Pool
Median Substrate	Gravel	Gravel
Stream Type	C	F

Ph2 Cross-Section Data

Curve Width (ft)	42.9
Bankfull Width (ft)	53
Max Depth (ft)	1.8
Width/Depth Ratio	29.2
Entrenchment Ratio	1.3
Incision Ratio	2.2

Crossing/Constriction Summary

Type	Location	% wbkf	Impacts
B	State	152%	D,E
B	State	117%	D,E

# of Other Constrictions: 0
# of Grade Controls: 4

Rapid Habitat Assessment

Rank	LWD	Pools
1	34	9
2	24	10
3	5	1
4	12	3
5	5	1
6	2	0
7	0	0
#/mile	50	14

Number of Debris Jams: 8

Step 6/7 Summary

RHA Score/Condition	77/Fair
Habitat Type Departure	None
RGA Score / Condition	33/Fair
Dominant Adjustment	Degradation
CEM Model Stage	F/II
Stream Type Departure	C to F
Stream Sensitivity	Extreme

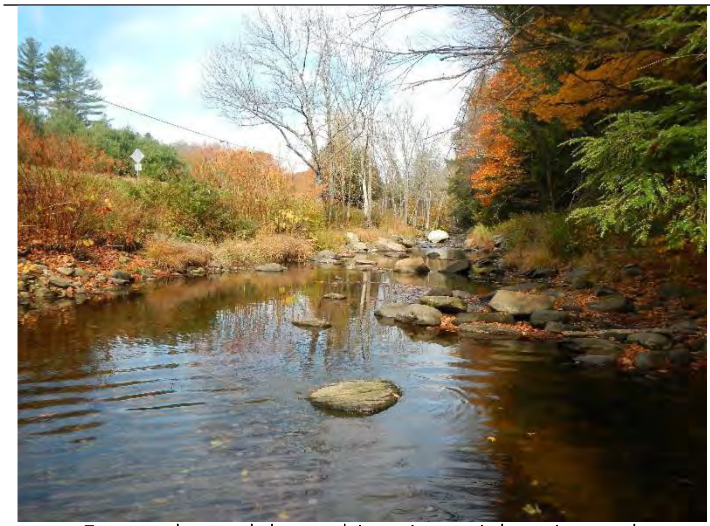
Impact Summary

Bank Erosion	Stormwater
Armoring	Constrictions
Riparian Buffer	Deposition
Encroachment	Migration
Development	Steep Riffle
Corridor Land Use	Head Cut
Mass Failure	Straightening
Flow Regulation	Dredging

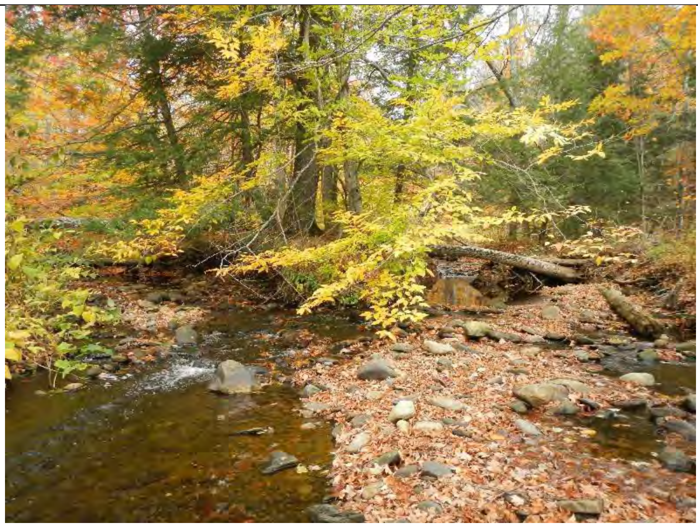
Potential Projects in Reach

- NR-10: Corridor Protection – Protect an important floodplain area through a permanent conservation easement.
- NR-11: Road Resiliency – Replace road embankment armor along an active secondary channel/flood chute.

Reach Highlights: Historically this reach was incised due to straightening, armoring, and encroachment along Rt 112. We assessed this reach as Stage II because incision and entrenchment that caused a stream type departure from a C to a F-type channel. The presence of several large flood chutes and splits in the channel suggest the channel maintains some ability to adjust planform within its valley.



F-type channel due to historic straightening and armoring.



Channels converge downstream of a bifurcation.

Stream: North River	Reach: T1.01	Town: Halifax	Date Assessed: 11/08/16
Channel Length (ft): 3,439	Channel Slope (%): 1.67	Sinuosity: 1.02	Watershed Area (mi^2): 9.58

Stream Type Summary

	P1 Reference	**P2 Assessed**
Confinement	Broad	Semi Confined
Bedform	Riffle-Pool	Riffle-Pool
Median Substrate	Cobble	Cobble
Stream Type	B_c	F

Ph2 Cross-Section Data

Curve Width (ft)	35.4
Bankfull Width (ft)	40
Max Depth (ft)	1.9
Width/Depth Ratio	23.4
Entrenchment Ratio	1.2
Incision Ratio	2.0

Crossing/Constriction Summary

Type	Location	% wbkf	Impacts

# of Other Constrictions: 2
# of Grade Controls: 0

Rapid Habitat Assessment

Rank	LWD	Pools
1	12	6
2	8	10
3	0	1
4	1	2
5	0	0
6	0	0
7	0	1
#/mile	32	30

Number of Debris Jams: 2

Step 6/7 Summary

RHA Score/Condition	89/Fair
Habitat Type Departure	None
RGA Score / Condition	35/Fair
Dominant Adjustment	Degradation
CEM Model Stage	F/II
Stream Type Departure	B_c to F
Stream Sensitivity	Extreme

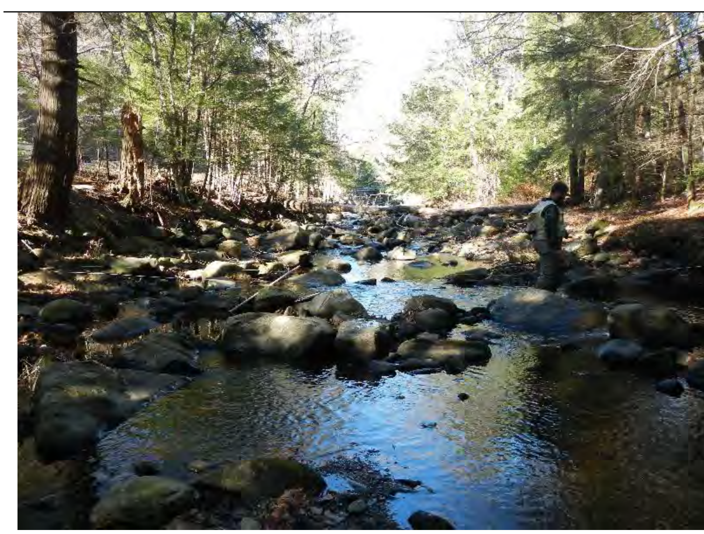
Impact Summary

Bank Erosion	Stormwater
Armoring	Constrictions
Riparian Buffer	Deposition
Encroachment	Migration
Development	Steep Riffle
Corridor Land Use	Head Cut
Mass Failure	Straightening
Flow Regulation	Dredging

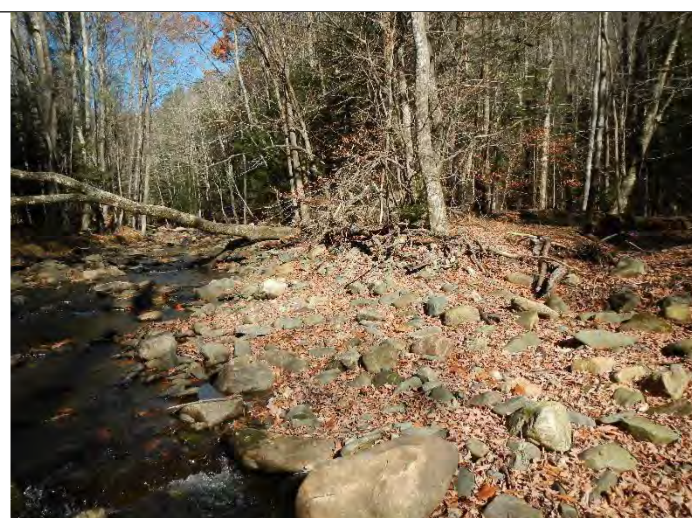
Potential Projects in Reach

- BB-1: Corridor Protection – Protect the active floodplain areas downstream of the Town Garage from future development.
- BB-2: Road Resiliency – Install new road embankment armor along a large floodchute immediately south of the Town Garage.
- BB-3: Road Resiliency – Replace failing road embankment armor and consider pushing the channel center away from the road to improve sediment transport and protect the road.

Reach Highlights: Historically this reach was incised due to straightening as well as armoring and encroachment along Branch Road. There was some evidence of channel widening with recent bank scour from T.S. Irene. The lower portion of the reach, near the confluence with North River, had several large flood chutes. Processes associated with incision were representative for most the reach and contributed to our assessment of the reach as Stage II.



F-type channel due to straightening and encroachment



Large flood chute rejoining the channel near the confluence of Branch Brook and the North River.

Stream: North River **Reach:** T1.02 **Town:** Halifax **Date Assessed:** 11/07/16

Channel Length (ft): 6,537 Channel Slope (%): 1.92 Sinuosity: 1.00 Watershed Area (mi^2): 7.76

Stream Type Summary

	P1 Reference	P2 Assessed
Confinement	Broad	Narrow
Bedform	Riffle-Pool	Riffle-Pool
Median Substrate	Cobble	Cobble
Stream Type	B_c	B_c

Ph2 Cross-Section Data

Curve Width (ft)	32.3
Bankfull Width (ft)	42
Max Depth (ft)	2.5
Width/Depth Ratio	27.7
Entrenchment Ratio	1.4
Incision Ratio	2.2

Crossing/Constriction Summary

Type	Location	% wbkf	Impacts
B	Private	68%	D,E
B	Town	136%	D
B	Private	87%	
B	Town	68%	D

# of Other Constrictions: 0
# of Grade Controls: 5

Rapid Habitat Assessment

Rank	LWD	Pools
1	9	9
2	20	5
3	1	4
4	5	3
5	1	0
6	1	1
7	0	1
#/mile	29	18

Number of Debris Jams: 3

Step 6/7 Summary

RHA Score/Condition	94/Fair
Habitat Type Departure	None
RGA Score / Condition	42/Fair
Dominant Adjustment	Degradation
CEM Model Stage	F/II
Stream Type Departure	None
Stream Sensitivity	High

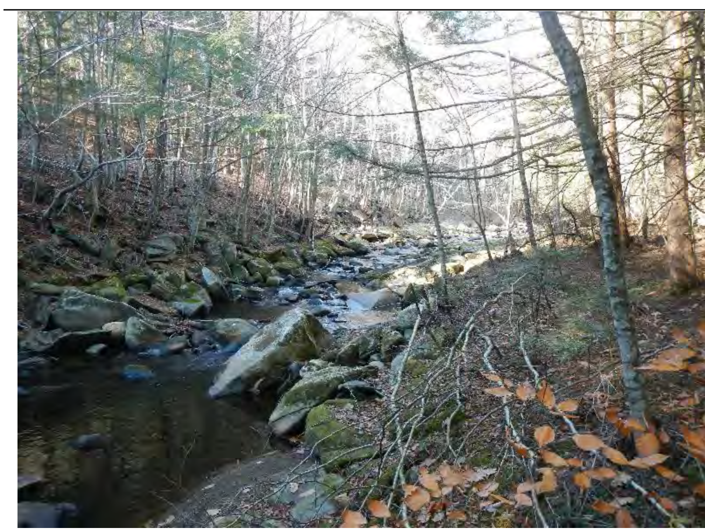
Impact Summary

Bank Erosion	Stormwater
Armoring	Constrictions
Riparian Buffer	Deposition
Encroachment	Migration
Development	Steep Riffle
Corridor Land Use	Head Cut
Mass Failure	Straightening
Flow Regulation	Dredging

Potential Projects in Reach

- BB-4: Bridge Retrofit – Stacked stone abutments under driveway bridge should be pulled back to increase bankfull width.
- BB-5: Stormwater – Several stormwater ditches and culverts along the road have unstable outlets with increased sediment load.
- BB-6: Road Resiliency – Small mass failure is threatening road.
- BB-7: Cattle Stream Access – Pasture area has several unstable stream access points, recommend establishing 2 armored accesses.

Reach Highlights: Historically this reach was incised due to straightening and development, as well as armoring and encroachment along Branch Road. Based on extensive scour we suspect that the channel incised during T.S. Irene. Further incision is very limited due to the presence of numerous grade controls and very large substrate throughout the reach. We observed some evidence of widening however this will be limited due to extensive road armoring and natural armoring along the banks. We assessed the reach as Stage II but it is likely slowly progressing to Stage III.


F-type channel due to straightening and encroachment.


Bank straightening and armoring along cow pasture.

4.1.2 Whitingham, VT Phase 2 Assessment Summary

The Phase 2 assessed reaches on the East Branch of the North River within the Town of Whitingham are described below (Figure 4.2).

- Reach M06
    - Reach M06 was divided into two segments based on impacts from development, armoring, and encroachment. The first segment (A) flows from shortly downstream of the intersection of Holbrook Road and VT 112 to near the intersection of VT 112 and Sprague Brook Road. Segment M06.A is characterized by incision, but to a lesser degree than the extreme incision in the upstream reach. Segment M06.B flows from just downstream of the intersection of VT 100 and VT 112 in the village of Jacksonville to where bank armoring and incision decrease downstream of the intersection with Holbrook Road and is characterized by incision due to extreme straightening, encroachment, and bank armoring in the village.
- Reach M07
    - Reach M07 was divided into two segments based on channel dimensions resulting from development, armoring, and encroachment impacts. The first segment (A) flows from just upstream of the Whitingham Municipal Center to just downstream of the crossing at the intersection of VT 112 and Rt 100. Segment M07.A is characterized by an extremely incised and armored channel in the Village of Jacksonville that does not allow adjustment processes to occur. The upstream segment (B) flows from the first crossing on VT 100 upstream of the village of Jacksonville to just upstream of the Whitingham Municipal Center. Segment M07.B is wider than the downstream reach and maintains the ability to move and access floodplains in its very broad valley.

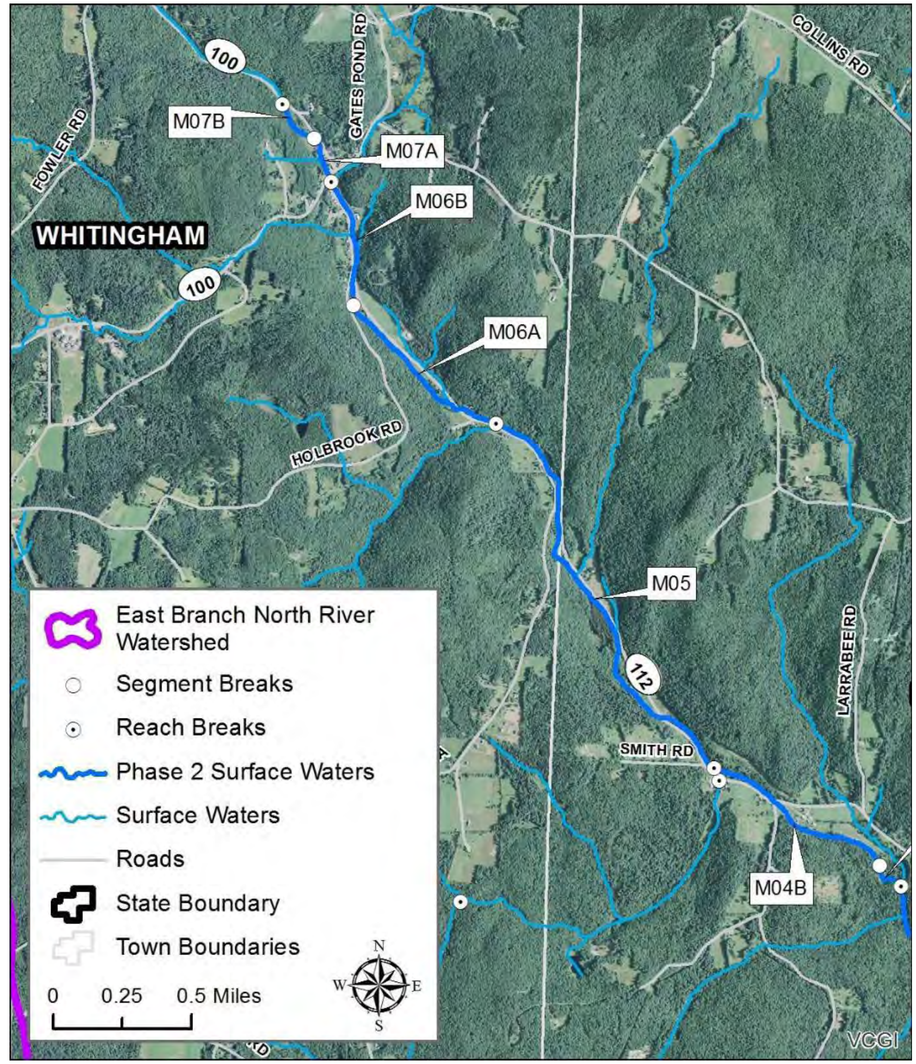


Figure 4.2: Whitingham, VT reach locations.

Stream: North River	Reach: M06.A	Town: Whitingham	Date Assessed: 11/08/16
Channel Length (ft): 3,731	Channel Slope (%): 1.46	Sinuosity: 1.00	Watershed Area (mi^2): 9.65

Stream Type Summary

	P1 Reference	P2 Assessed
Confinement	Very Broad	Narrow
Bedform	Riffle-Pool	Riffle-Pool
Median Substrate	Cobble	Gravel
Stream Type	C	B

Ph2 Cross-Section Data

Curve Width (ft)	35.5
Bankfull Width (ft)	27
Max Depth (ft)	2.3
Width/Depth Ratio	16.3
Entrenchment Ratio	1.9
Incision Ratio	1.9

Crossing/Constriction Summary

Type	Location	% wbkf	Impacts
B	State	113%	D,E

# of Other Constrictions: 0
# of Grade Controls: 0

Rapid Habitat Assessment

Rank	LWD	Pools
1	14	4
2	17	9
3	3	0
4	5	2
5	0	0
6	2	0
7	0	1
#/mile	58	22

Number of Debris Jams: 4

Step 6/7 Summary

RHA Score/Condition	90/Fair
Habitat Type Departure	None
RGA Score / Condition	55/Fair
Dominant Adjustment	Degradation
CEM Model Stage	F/II
Stream Type Departure	C to B
Stream Sensitivity	Very High

Impact Summary

Bank Erosion	Stormwater
Armoring	Constrictions
Riparian Buffer	Deposition
Encroachment	Migration
Development	Steep Riffle
Corridor Land Use	Head Cut
Mass Failure	Straightening
Flow Regulation	Dredging

Potential Projects in Reach

- NR-12: Berm Removal – A small historic berm is restricting access to a long and narrow floodplain, berm does not protect any infrastructure. Buffer plants should be included along the top of bank.

Reach Highlights: Historically this reach was incised due to straightening and encroachment along VT 112. We did not see evidence of much widening, aggradation or planform adjustment. Processes associated with incision contributed to our assessment of the reach as Stage II. The stream departed from a C to a B-type channel due to incision and entrenchment.

F-type channel due to historic straightening and encroachment.

Historically straightened channel with an old berm on the left bank.

Stream: North River	Reach: M06.B	Town: Whitingham	Date Assessed: 11/08/16
Channel Length (ft): 2,498	Channel Slope (%): 1.46	Sinuosity: 1.00	Watershed Area (mi^2): 9.65

Stream Type Summary

	P1 Reference	P2 Assessed
Confinement	Very Broad	Narrow
Bedform	Riffle-Pool	Riffle-Pool
Median Substrate	Cobble	Gravel
Stream Type	C	F

Ph2 Cross-Section Data

Curve Width (ft)	35.5
Bankfull Width (ft)	20
Max Depth (ft)	2.8
Width/Depth Ratio	9.0
Entrenchment Ratio	1.2
Incision Ratio	3.0

Crossing/Constriction Summary

Type	Location	% wbkf	Impacts
B	Private	73%	
B	State	225%	D,E
B	Town	84%	D
B	Town	79%	D
B	Town	73%	
B	Town	56%	D

# of Other Constrictions: 0
# of Grade Controls: 3

Rapid Habitat Assessment

Rank	LWD	Pools
1	0	1
2	0	0
3	0	0
4	1	2
5	0	0
6	1	0
7	0	0
#/mile	1	6

Number of Debris Jams: 1

Step 6/7 Summary

RHA Score/Condition	55/Poor
Habitat Type Departure	Plane Bed
RGA Score / Condition	29/Poor
Dominant Adjustment	Degradation
CEM Model Stage	F/II
Stream Type Departure	C to F
Stream Sensitivity	Extreme

Impact Summary

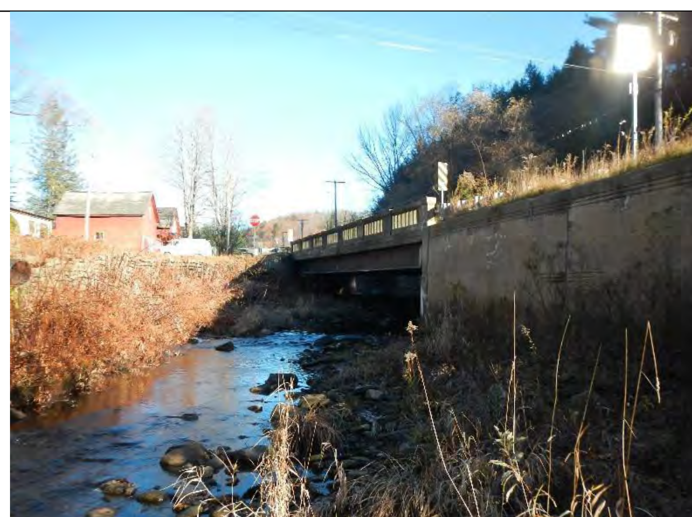
Bank Erosion	Stormwater
Armoring	Constrictions
Riparian Buffer	Deposition
Encroachment	Migration
Development	Steep Riffle
Corridor Land Use	Head Cut
Mass Failure	Straightening
Flow Regulation	Dredging

Potential Projects in Reach

- NR-13: Infrastructure Resiliency – Replace bank armor to widen channel and considering lowering floodplain elevation.
- NR-14: Utility Resiliency – Suspected sewer line under stream is highly vulnerable to scour.
- NR-15: Buffer Planting – the parking area and rip-rap wall along the channel have no vegetation to provide shade.
- NR-16: Bridge Replacement – Bridge is undersized and increases risk of flood damage to adjacent houses.

Reach Highlights: Historically this reach was incised due to straightening and encroachment along VT 112, as well as extensive armoring through the village of Jacksonville. The armored banks prevent widening and planform adjustment. Extensive straightening has degraded channel bed features resulting in a plane bed stream. Processes associated with incision contributed to our assessment of the reach as Stage II. The stream departed from a C to a F- type channel due to incision and entrenchment.

F-type channel due to straightening and armoring.



Incised channel at the intersection of VT 112 and Holbrook Road.

Stream: North River	Reach: M07.A	Town: Whitingham	Date Assessed: 11/07/16
Channel Length (ft): 927	Channel Slope (%): 2.0	Sinuosity: 1.01	Watershed Area (mi^2): 1.48

Stream Type Summary

	P1 Reference	P2 Assessed
Confinement	Very Broad	Very Broad
Bedform	Riffle-Pool	Riffle-Pool
Median Substrate	Cobble	Gravel
Stream Type	C	F

Ph2 Cross-Section Data

Curve Width (ft)	15.6
Bankfull Width (ft)	13
Max Depth (ft)	1.8
Width/Depth Ratio	10.1
Entrenchment Ratio	1.2
Incision Ratio	2.6

Crossing/Constriction Summary

Type	Location	% wbkf	Impacts
B	State	38%	
C	Town	55%	
B	Town	26%	S

# of Other Constrictions: 0
# of Grade Controls: 0

Rapid Habitat Assessment

Rank	LWD	Pools
1	2	2
2	1	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
#/mile	17	11

Number of Debris Jams: 2

Step 6/7 Summary

RHA Score/Condition	55/Poor
Habitat Type Departure	Plane Bed
RGA Score / Condition	25/Poor
Dominant Adjustment	Degradation
CEM Model Stage	F/II
Stream Type Departure	C to F
Stream Sensitivity	Extreme

Impact Summary

Bank Erosion	Stormwater
Armoring	Constrictions
Riparian Buffer	Deposition
Encroachment	Migration
Development	Steep Riffle
Corridor Land Use	Head Cut
Mass Failure	Straightening
Flow Regulation	Dredging

Potential Projects in Reach

- NR-17: Bridge Replacement – The extremely undersized bridge under the VT 100/VT 112 intersection is a major flood hazard.
- NR-18: Culvert Replacement – The Municipal Center culvert is undersized and slightly perched.
- NR-19: Bridge Removal – The redundant bridge to access the Municipal Center is extremely undersized and caused extensive flooding during T.S. Irene.

Reach Highlights: Historically this segment was incised due to straightening and encroachment along VT 100, as well as extensive armoring through the village of Jacksonville, VT. The armored banks prevent widening and planform adjustment. Extensive straightening has degraded channel bed features resulting in a plane bed stream. Processes associated with incision contributed to our assessment of the segment as Stage II. The stream departed from a C to a F-type channel due to incision and entrenchment.

F-type channel due to historic straightening, encroachment, and armoring.

Bank armoring and constrictions at the Whitingham Municipal Complex.

Stream: North River	Reach: M07.B	Town: Whitingham	Date Assessed: 11/07/16
Channel Length (ft): 948	Channel Slope (%): 2.0	Sinuosity: 1.01	Watershed Area (mi^2): 1.48

Stream Type Summary

	P1 Reference	P2 Assessed
Confinement	Very Broad	Very Broad
Bedform	Riffle-Pool	Riffle-Pool
Median Substrate	Cobble	Gravel
Stream Type	C	C

Ph2 Cross-Section Data

Curve Width (ft)	15.6
Bankfull Width (ft)	20
Max Depth (ft)	1.8
Width/Depth Ratio	16.3
Entrenchment Ratio	3.8
Incision Ratio	1.4

Crossing/Constriction Summary

Type	Location	% wbkf	Impacts

# of Other Constrictions: 0
# of Grade Controls: 0

Rapid Habitat Assessment

Rank	LWD	Pools
1	3	2
2	3	2
3	0	0
4	1	0
5	0	0
6	1	0
7	0	0
#/mile	44	22

Number of Debris Jams: 0

Step 6/7 Summary

RHA Score/Condition	104/Good
Habitat Type Departure	None
RGA Score / Condition	57/Good
Dominant Adjustment	None
CEM Model Stage	F/IV
Stream Type Departure	None
Stream Sensitivity	Moderate

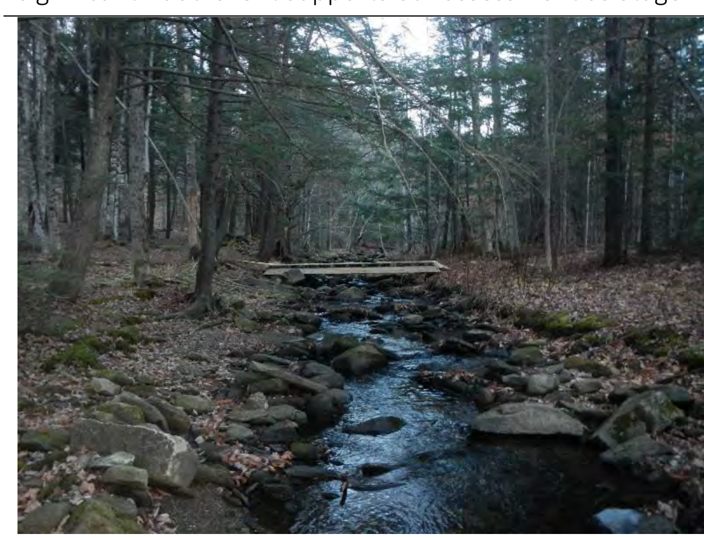
Impact Summary

Bank Erosion	Stormwater
Armoring	Constrictions
Riparian Buffer	Deposition
Encroachment	Migration
Development	Steep Riffle
Corridor Land Use	Head Cut
Mass Failure	Straightening
Flow Regulation	Dredging

Potential Projects in Reach

- NR-20: Corridor Protection – The forested area upstream of the Municipal Center provides important floodplain storage and should be protected from development.

Reach Highlights: Historically this segment experienced some encroachment from VT 100. The channel is slightly incised and widened but has retained floodplain access and appears stable. Further incision and widening is limited by the large substrate present along the banks and channel bed. We observed increased sand and gravel through the segment, likely coming from upstream bank erosion or mass failure. The relative stability of the reach following a recent significant flood event supports our assessment as Stage I.



C-type channel in very broad valley.

Floodplain access along channel.

4.2 Phase 2 Results Summary

Rapid Habitat Assessment (RHA) and Rapid Geomorphic Assessment (RGA) scores for all Phase 2 reaches/segments are summarized in Table 4.2 and Figures 4.4 and 4.5. FEA divided the "Fair" category into "Low Fair" and "High Fair" to better indicate which reaches were closer to "Poor" or "Good" respectively. The "Fair" scores were split at the numerical mean for the categories (49%). Detailed summaries of geomorphic data for each segment are provided in Appendix B. Habitat assessment summary data is provided in Appendix C.

Table 4.2: Summary RHA and RGA data for all Phase 2 Reaches and Segments.

Stream	Reach/Segment	RHA Score	RHA Condition	RGA Score	RGA Condition
East Branch North River	M02	54%	High-Fair	40%	Low-Fair
	M03.A	48%	Low-Fair	44%	Low-Fair
	M03.B		*		Reference*
	M03.C	64%	High-Fair	60%	High-Fair
	M04.A		*		*
	M04.B	51%	High-Fair	44%	Low-Fair
	M05	48%	Low-Fair	41%	Low-Fair
	M06.A	56%	High-Fair	60%	High-Fair
	M06.B	34%	Poor	36%	Poor
	M07.A	34%	Poor	31%	Poor
	M07.B	65%	Good	71%	Good
Branch Brook	T1.01	56%	High-Fair	44%	Low-Fair
	T1.02	59%	High-Fair	52%	High-Fair

*RHA and RGA assigned based on administrative judgment, full assessment not conducted on M03B and M04A

Figure 4.3: Pebble count data collection on M04B.

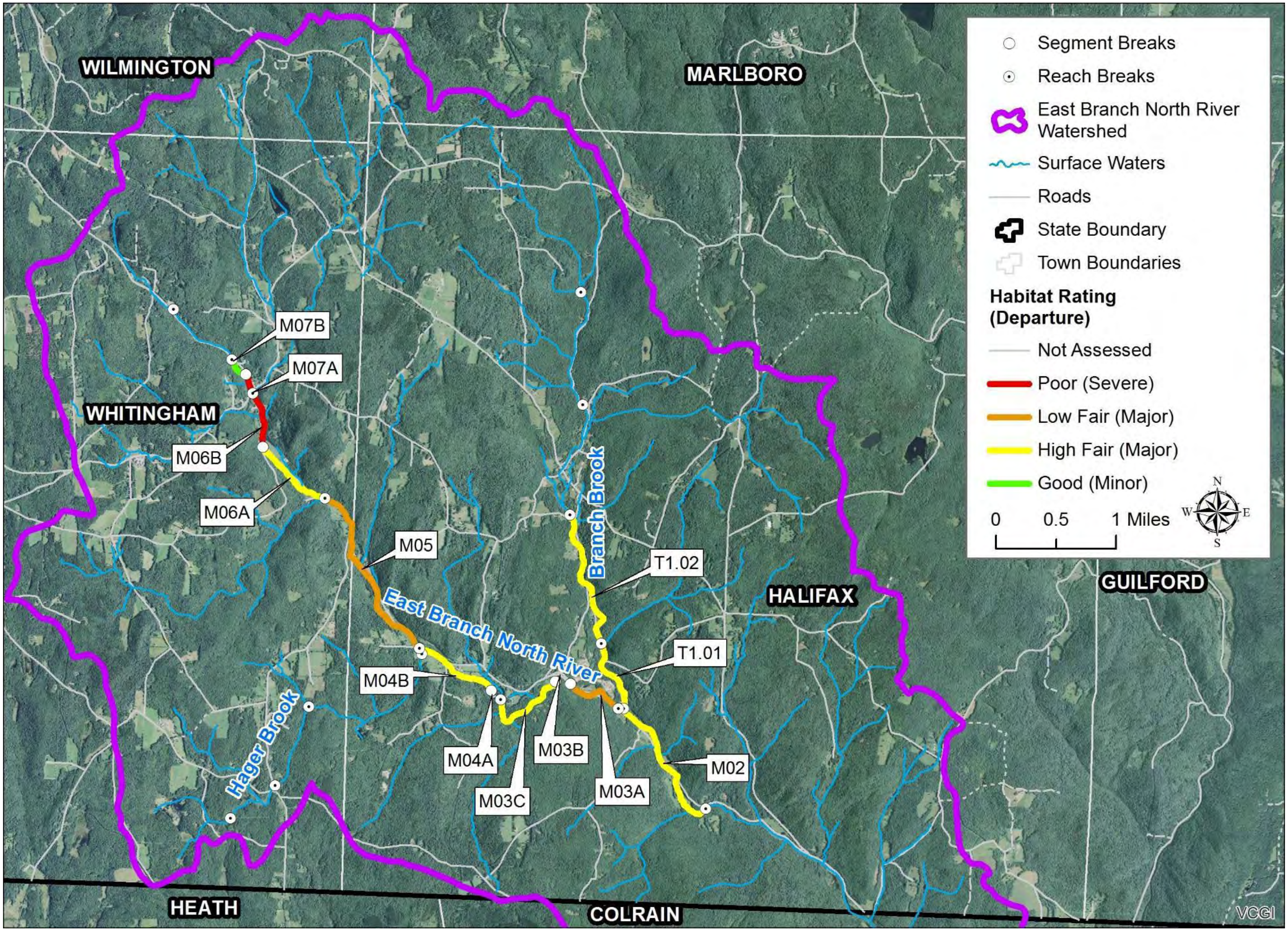


Figure 4.4: Rapid Habitat Assessment Ratings for the East Branch North River Watershed.

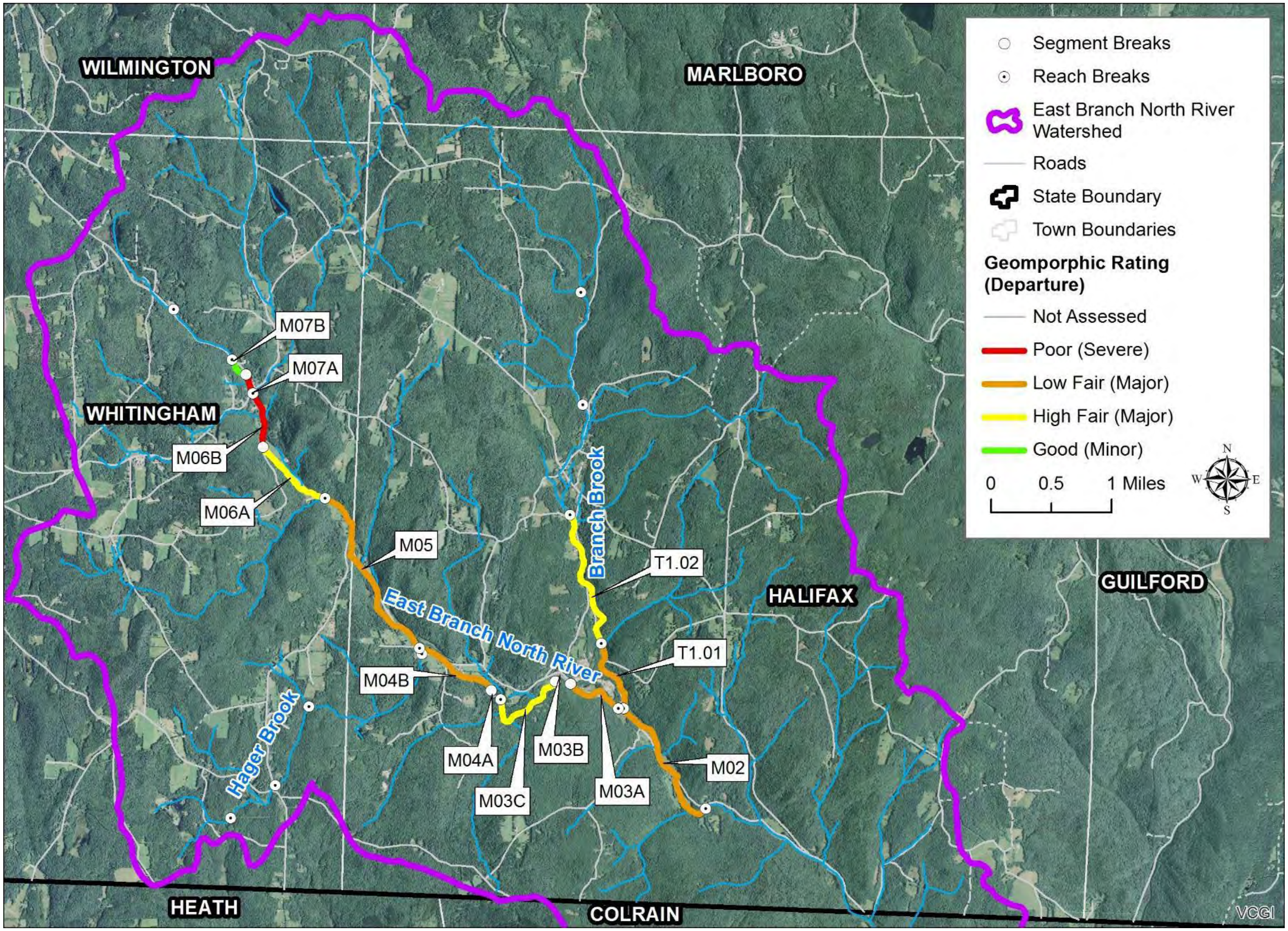


Figure 4.5: Rapid Geomorphic Assessment Ratings for the East Branch North River Watershed.

4.3 River Corridor Planning

The following sections summarize the stressor identification and departure maps. The data collected through the Phase 1 and 2 SGA studies provides the basis for assessing the impacts to the hydrologic and sediment regimes, and the channel riparian and boundary conditions. These data, when combined with other watershed-scale data developed in this study, allow for the assessment of physical departure from reference conditions, and serve to confirm watershed-scale patterns and stream conditions observed in the field. The mapping of physical stressors and natural or human constraints allowed for 1) a process-based approach to understanding stream conditions at different scales, and 2) an evaluation of the connectivity of stressors along the channel network. The maps were referenced during the project identification process summarized in Section 5.0.

4.3.1 Stressor Maps

Modifications to Riparian and Boundary Condition

The boundary conditions of a river encompass the bed and bank substrate, and the vegetation and root material found along the riverbank. Human alterations to the river boundary conditions are often made to increase the resistance of the banks and bed to reduce lateral and vertical adjustments. However, extensive removal of riparian vegetation in the absence of bank hardening can cause a decrease in boundary resistance, and lead to increased lateral migration. Other natural and human-installed features within the channel, such as bedrock ledges and dams, affect boundary resistance in an upstream and downstream direction by controlling vertical adjustment processes.

Alterations to the channel boundary conditions and riparian areas in the East Branch North River study area have been mapped using the variables extracted from the Phase 2 field dataset (Figure 4.16). Bank armoring (e.g., rip-rap) highlights areas of increased resistance to lateral migration, whereas bank erosion highlights reaches where significant lateral adjustments are found. Additional data showing the location of natural and man-made channel features (e.g., ledges and dam) depict areas that have a resistance to channel change.

Areas influencing riparian zone and boundary conditions include:

Increased Boundary Resistance

- Areas with numerous natural grade control on segments: M03B, M03C, M05, T1.02 (Figures 4.6 and 4.7).
- Beaver dams are located on segments M02, M04.A, M06.A (Figure 4.8) and a small cobble impoundment is located on segment M03.C (Figure 4.9).
- Extreme bank armoring on segments M06B and M07A (Figures 4.10 and 4.11). Extensive bank armoring on segments M02, M03.A, M04B, M05, M06.A, M07.B, T1.01, T1.02.

Decreased Boundary Resistance

- Moderate bank erosion in segments: M04.B, M05, M06.A (Figures 4.12 and 4.13).
- Multiple mass failures in segments: M03.C and M05 (Figures 4.14 and 4.15).

- Dredging in segments: M02, M04.A, M04.B (Figures 4.21 and 4.22).
- High density of riparian buffer width impacts in segments: M02, M03.A, M05, M06.A, M06.B, M07.A, T1.01, T1.02.

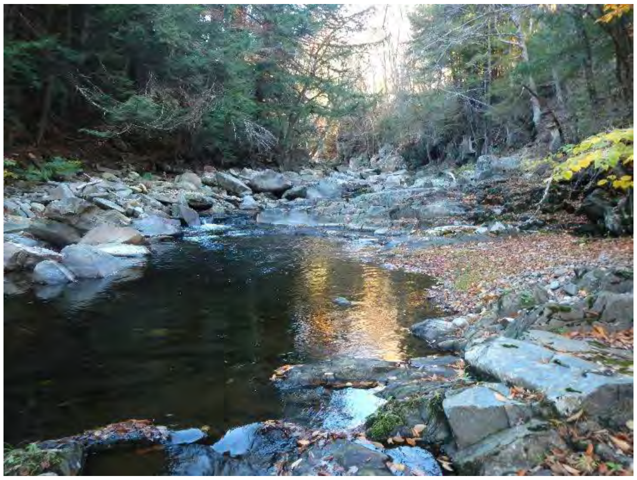


Figure 4.6: Grade controls in segment M03.B.

Figure 4.7: Grade controls in reach M05.

Figure 4.8: Beaver dam in reach M02.

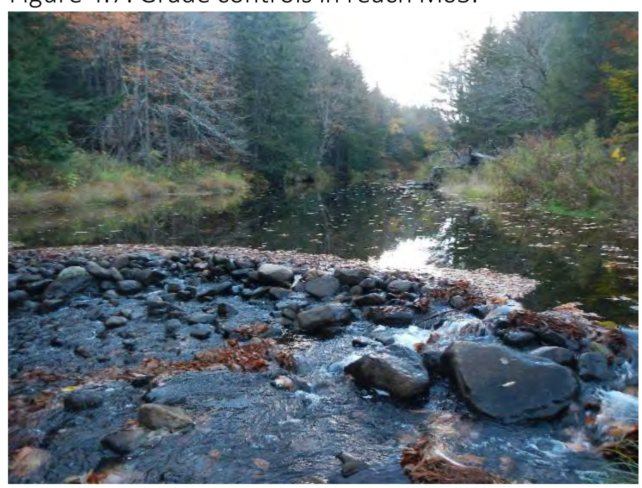


Figure 4.9: Small boulder & cobble impoundment to enhance a swimming hole in segment M03.C.

Figure 4.10: Extreme bank armoring on reach M06.B.

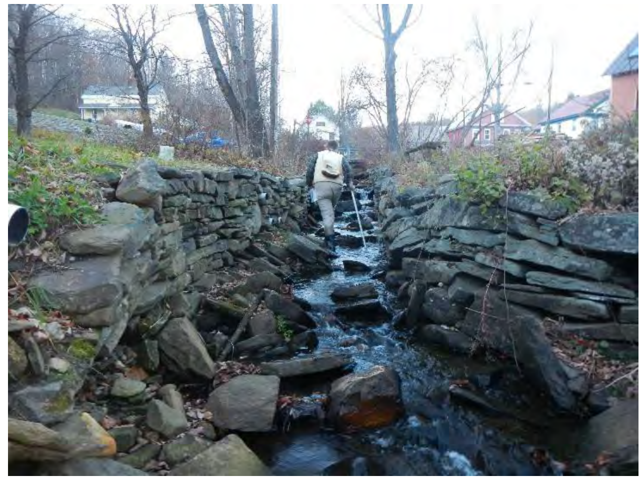


Figure 4.11: Extreme bank armoring on segment M07.A.

Figure 4.12: Bank erosion and failing armoring along VT 112 on reach M05.

Figure 4.13: Bank erosion near Holbrook Road on segment M06.A.

Figure 4.14: Mass failure on segment M03.C.

Figure 4.15: Mass failure on reach M05.

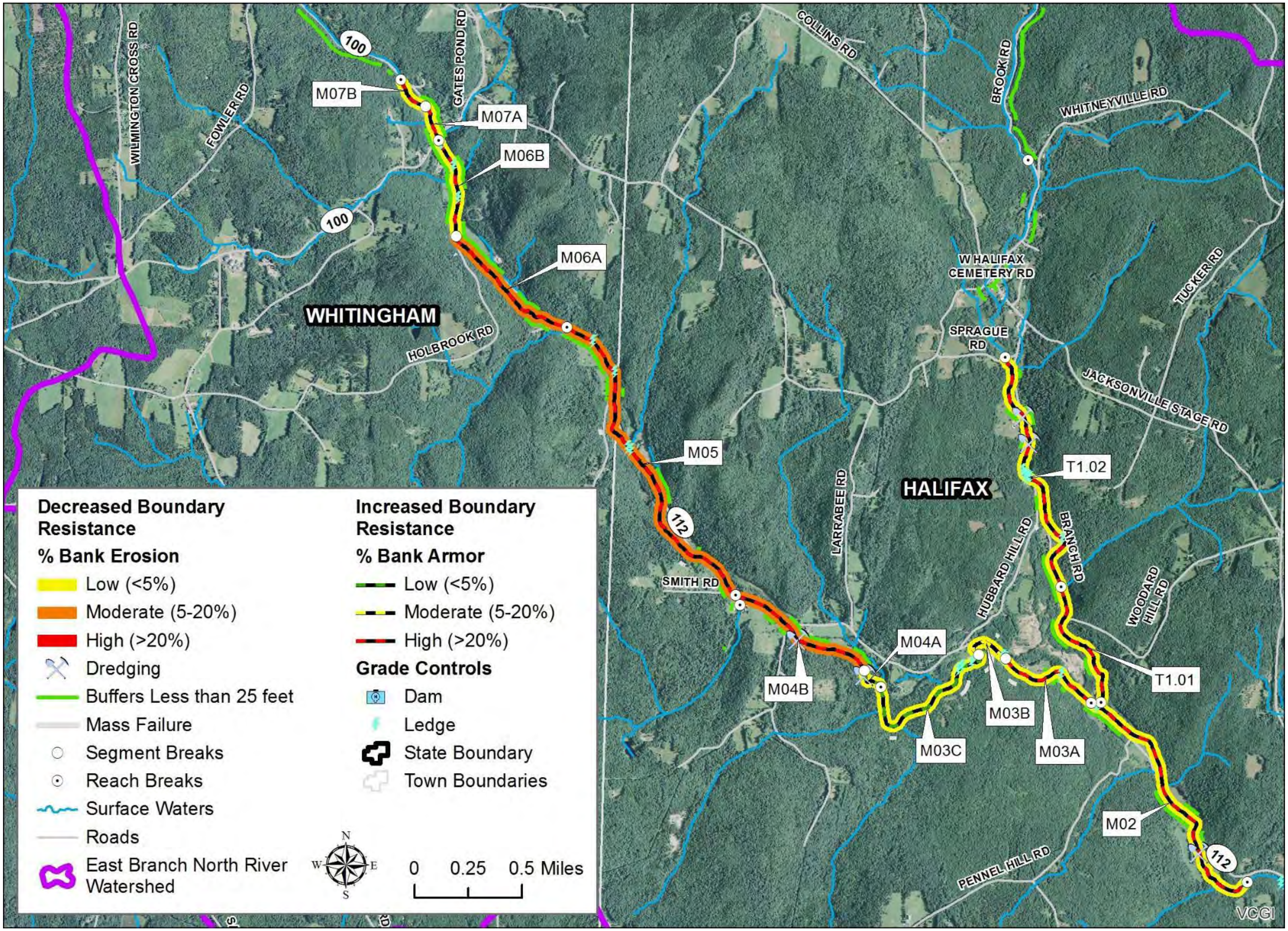


Figure 4.16: Riparian and boundary condition modifiers for the East Branch North River watershed.

Channel Slope and Depth Modifiers

Many of Vermont's rivers and streams have been historically manipulated and straightened to maintain an unnaturally steep slope, allowing for a short term sense of security from flooding and subsequent encroachment of infrastructure in the floodplain. Over time, many alluvial rivers will seek to redevelop a sinuous planform through the deposition of sediments in unconfined valleys. Following flood events when alluvial rivers become energized enough to transport large amounts of coarse sediment into depositional zones of the watershed, lateral channel migration intensifies and further channel straightening is required to protect infrastructure found in the floodplain. In larger alluvial rivers of Vermont, straightening and channelization typically ranges between 25 and 75 percent of the total river channel length (VTANR, 2010).

In addition to historic alterations to channel slope in Vermont's alluvial rivers, the lowering of stream beds (e.g., dredging) and the raising of floodplains (e.g., encroachments) have resulted in an increase in channel depth (VTANR, 2010). Channel depths have typically been increased through the encroachment on the floodplain by roads and railroads and subsequent filling and armoring required to construct and maintain this infrastructure. Increases in impervious cover have also led to the deepening and eventual widening of channels throughout urbanized areas of Vermont (Fitzgerald, 2007).

Alterations to channel slope and depth in the East Branch North River study area have been mapped using the variables extracted from the Phase 2 field dataset (Figure 4.23). Areas of channel straightening mapped during the Phase 1 and 2 assessments are included to depict areas of increased channel slope. Corridor encroachment data highlights where roads and development have reduced the floodplain area, typically resulting in increased stream power and channel deepening. Additional data showing the location of natural channel features (e.g., ledges) and man-made features (e.g., dams) depict areas more resistant to vertical channel change.

Areas impacted by increases in slope and depth or influenced by controls on slope and depth include:

Increases in Slope and Depth

- Extreme channel straightening in segment: M02, M03.A, M04.B, M05, M06.A, M06.B, M07.A, T1.01 (Figure 4.17).
- High straightening in segments: M03.B, M07.B, T1.02 (Figure 4.18).
- Extreme corridor encroachments from berms and adjacent roadways and embankments in segment: M03.A, M04B, M05, M06.A, M06.B, M07.A, T1.01, T1.02. (Figures 4.19 and 4.20).
- Very high corridor encroachments in segment: M02 and M07.B.
- Dredging in segments: M02, M04A, M04.B (Figures 4.21 and 4.22).

Controls on Slope and Depth

- Areas with numerous natural grade control on segments: M03.B, M03.C, M05, T1.02 (Figures 4.6 and 4.7).
- Beaver dams are located on segments M02, M04.A, M06.A (Figure 4.8) and a small cobble impoundment is located on segment M03.C (Figure 4.9).

Figure 4.17: Extreme straightening along segment M06.B.

Figure 4.18: Bank armoring, encroachment, and straightening on reach T1.02.

Figure 4.19: Extreme encroachment along VT 112 on segment M03.A.

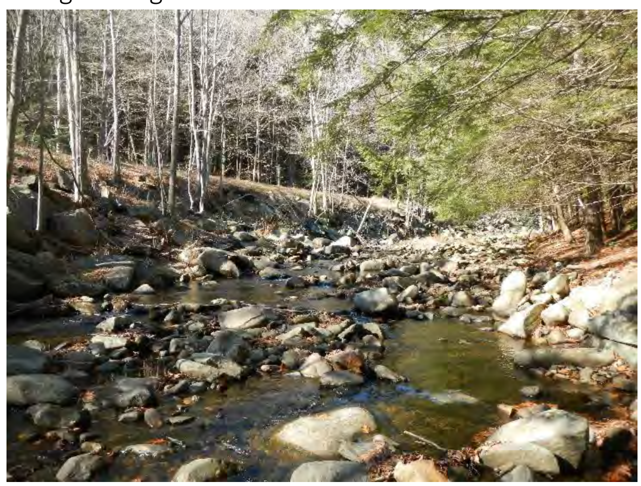


Figure 4.20: Extreme encroachment along Branch Road on reach T1.01.

Figure 4.21: Dredging and windrowing on reach M02.

Figure 4.22: Dredging spoils on segment M04.A.

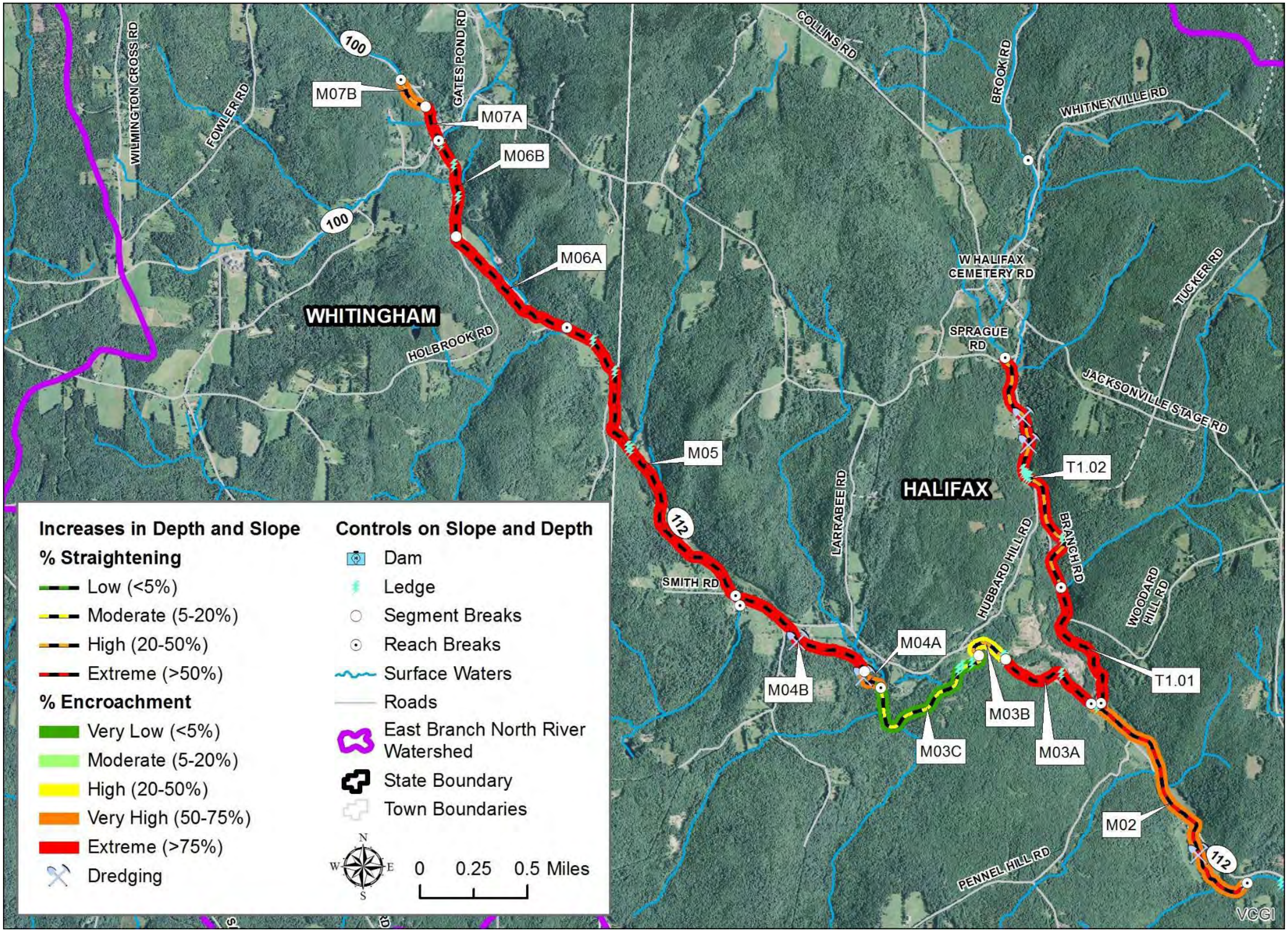


Figure 4.23: Controls on slope and depth for the East Branch North River watershed.

4.3.2 Departure Analysis

The reference and existing sediment regime types have been mapped using data from the Phase 1 and 2 assessments (Figures 4.24 and 4.25). Seven reaches in the East Branch North River study area have undergone a departure in both sediment regime and stream type due to channel incision as a result of: 1) historical land uses, 2) encroachments or development in the river corridor, or 3) extensive straightening and bank armoring. Many of the channel adjustments caused by these historic stressors were exacerbated by the Tropical Storm Irene in 2011, leading to further stream type departure~~s.~~ M03A, M03B, M03C, M04A, M07B, and T1.02 were the only Phase 2 study segments that were assessed as stable and did not contain a stream type departure and/or a sediment regime departure.

Stream type departures (per Rosgen, 1994) are summarized below (Table 4.3) to better describe the reaches where physical changes in channel morphology have accompanied sediment regime changes.

Table 4.3: Summary of stream type departures from reference conditions.

Phase 2 Segment ID	Stream Type Departure	Dominant Adjustment Type
M02	C to F	Historic Encroachment & Straightening/Incision
M04B	C to F	Historic Encroachment & Straightening/Incision
M05	C to F	Historic Encroachment & Straightening/Incision
M06A	C to B	Historic Encroachment & Straightening/Incision
M06B	C to F	Historic Development, Encroachment & Straightening/Incision
M07A	C to F	Historic Development, Encroachment & Straightening/Incision
T1.01	Bc to F	Historic Encroachment & Straightening/Incision

In addition to these morphological stream type departures, two reaches/segments (M03.A and T1.02) have undergone departures in sediment regimes in the absence of stream type departures. All sediment regime departures are summarized below in Table 4.4. An additional map summarizing channel adjustment processes for each reach/segment is included in Figure 4.26.

Table 4.4: Summary of Sediment Regime Departures.

Phase 2 Segment ID	Reference Sediment Regime	Existing Sediment Regime	Cause of Departure
M02	Coarse Equilibrium and Fine Deposition	Unconfined Source and Transport	Historic straightening/encroachment
M03A	Coarse Equilibrium and Fine Deposition	Transport	Historic straightening/encroachment
M04B	Coarse Equilibrium and Fine Deposition	Confined Source and Transport	Historic straightening/encroachment
M05	Coarse Equilibrium and Fine Deposition	Unconfined Source and Transport	Historic straightening/encroachment
M06A	Coarse Equilibrium and Fine Deposition	Unconfined Source and Transport	Historic straightening/encroachment
M06B	Coarse Equilibrium and Fine Deposition	Unconfined Source and Transport	Historic straightening/encroachment
M07A	Coarse Equilibrium and Fine Deposition	Unconfined Source and Transport	Historic straightening/encroachment
T1.01	Coarse Equilibrium and Fine Deposition	Confined Source and Transport	Historic straightening/encroachment
T1.02	Coarse Equilibrium and Fine Deposition	Confined Source and Transport	Historic straightening/encroachment

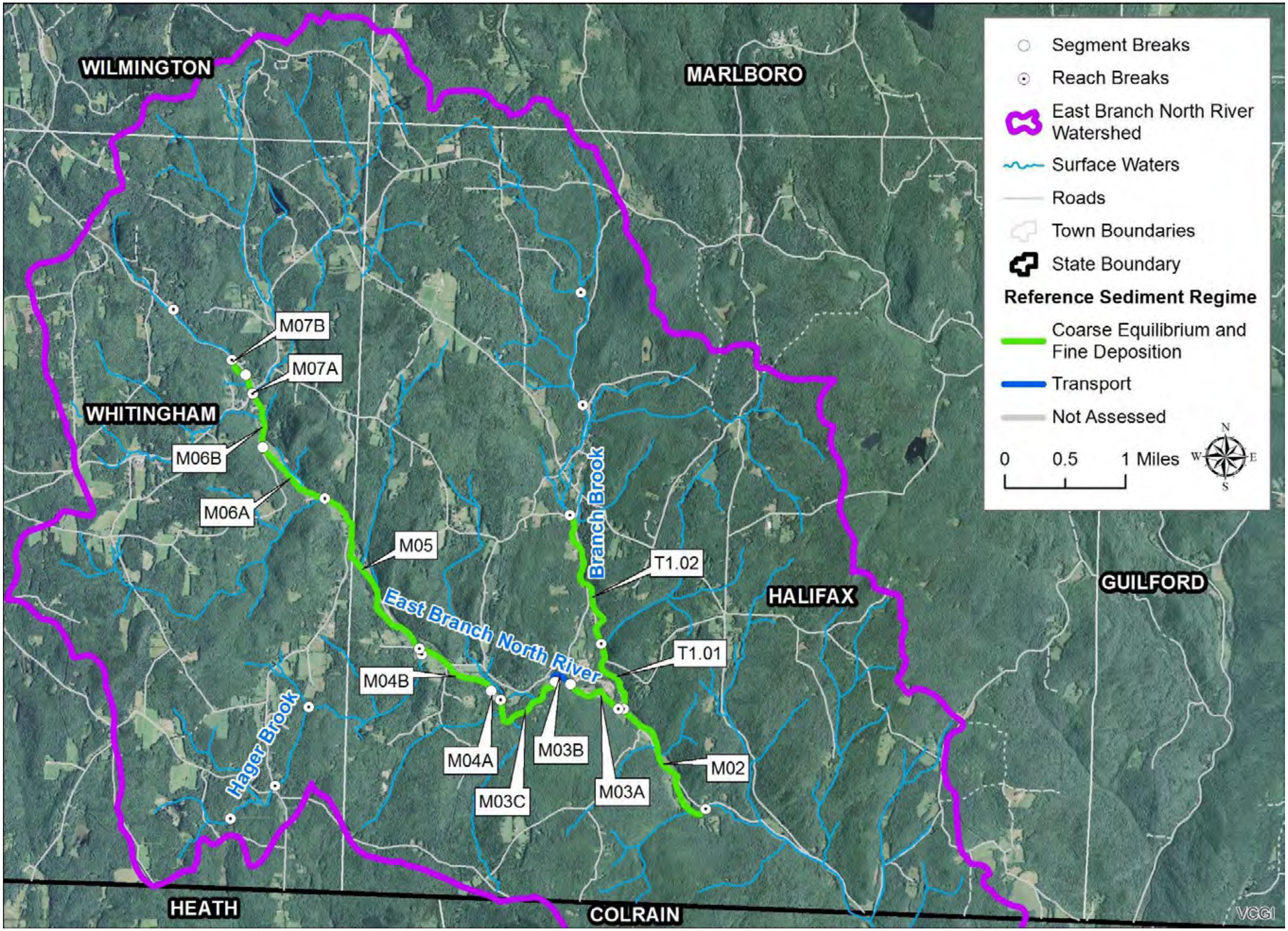


Figure 4.24: Reference Sediment Regime for the East Branch North River watershed.

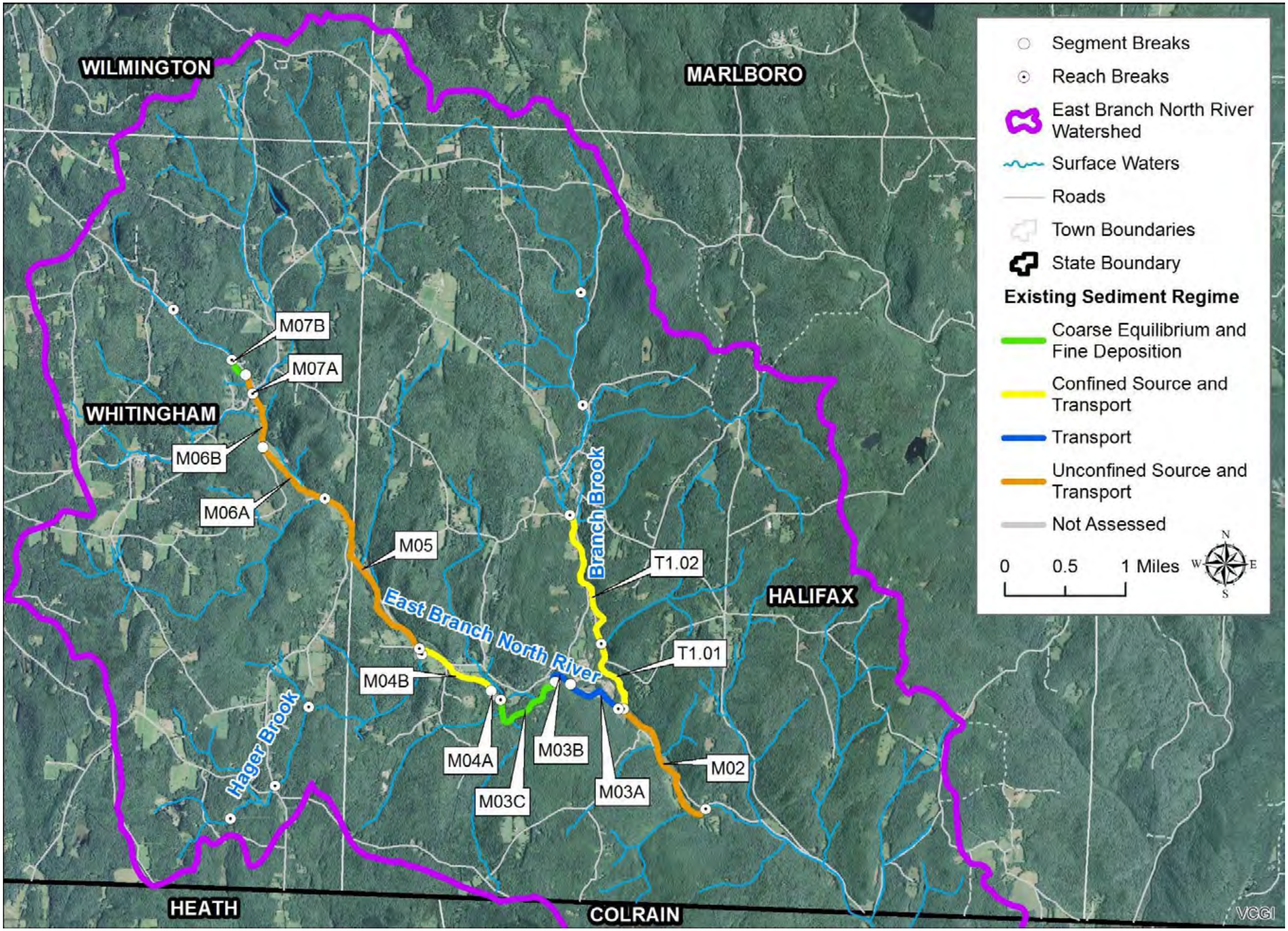


Figure 4.25: Existing Sediment Regime for the East Branch North River watershed.

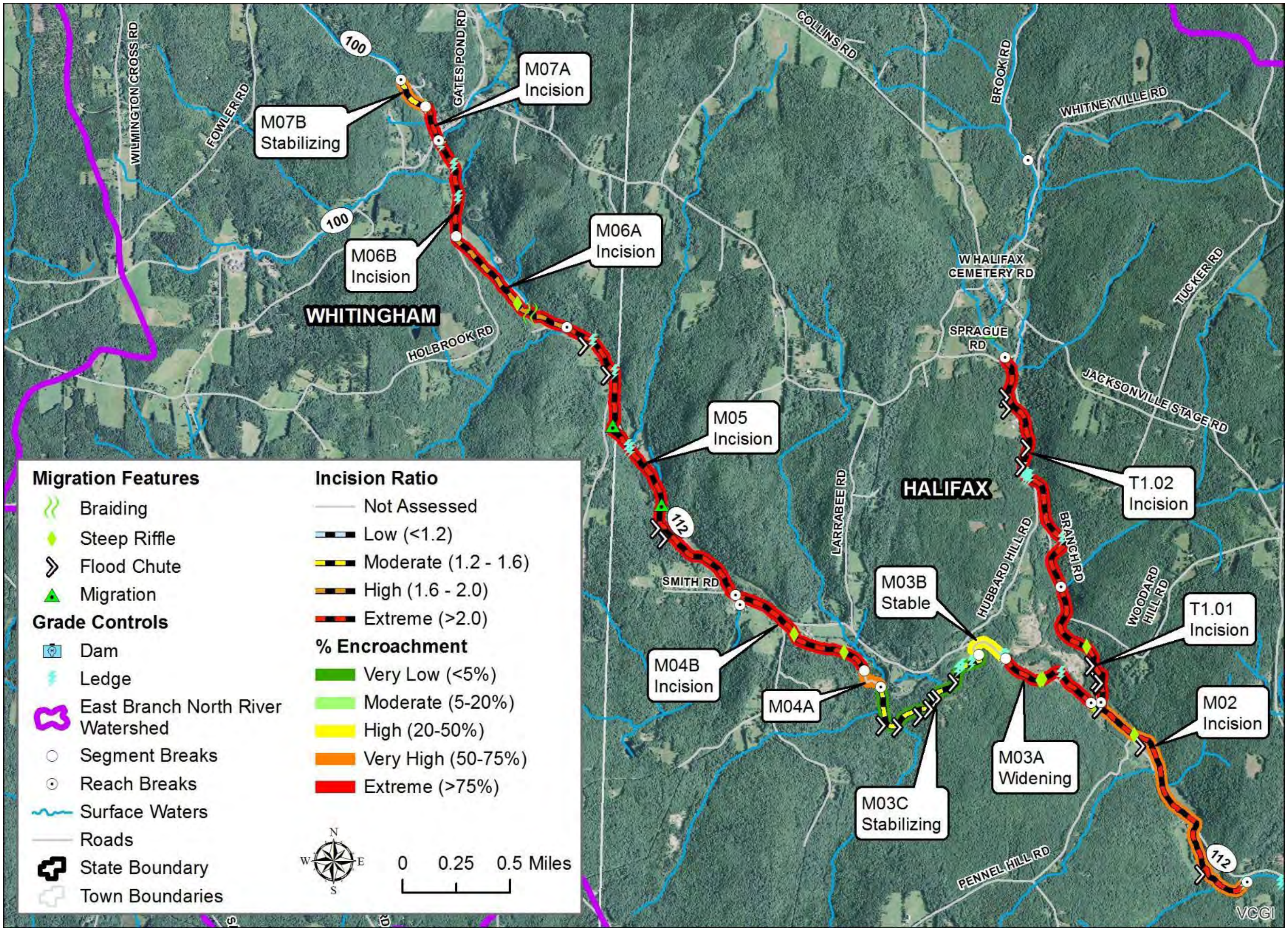


Figure 4.26: Channel Adjustment Process Map for the East Branch North River watershed.

4.3.3 Sensitivity Analysis

The methods outlined in the VTANR Corridor Planning Guide have been used to describe the stream sensitivities of the segments in the East Branch North River study area. Using the stream geometry and substrate data in conjunction with overall geomorphic stability (RGA score) as determined during the Phase 2 surveys, stream sensitivity ratings have been assigned to each segment (Figure 4.27). Six (6) segments have heightened sensitivities of "Extreme" due to human impacts. The increased stream sensitivity ratings are most often because of stream type departures (STD) (Table 4.5).

Incision due to encroachment, armoring, and/or straightening was the most common driver for "Extreme" sensitivity ratings in the study area.

Table 4.5: Extreme sensitivity segments and descriptions of the specific impacts and adjustments.

Phase 2 Segment ID	Stream Sensitivity	Description of Impacts
M02	Extreme	STD, Straightening, Encroachment, Incision
M04B	Extreme	STD, Straightening, Encroachment, Incision
M05	Extreme	STD, Straightening, Encroachment, Incision
M06B	Extreme	STD, Straightening, Armoring, Incision
M07A	Extreme	STD, Straightening, Armoring, Incision
T1.01	Extreme	STD, Encroachment, Incision

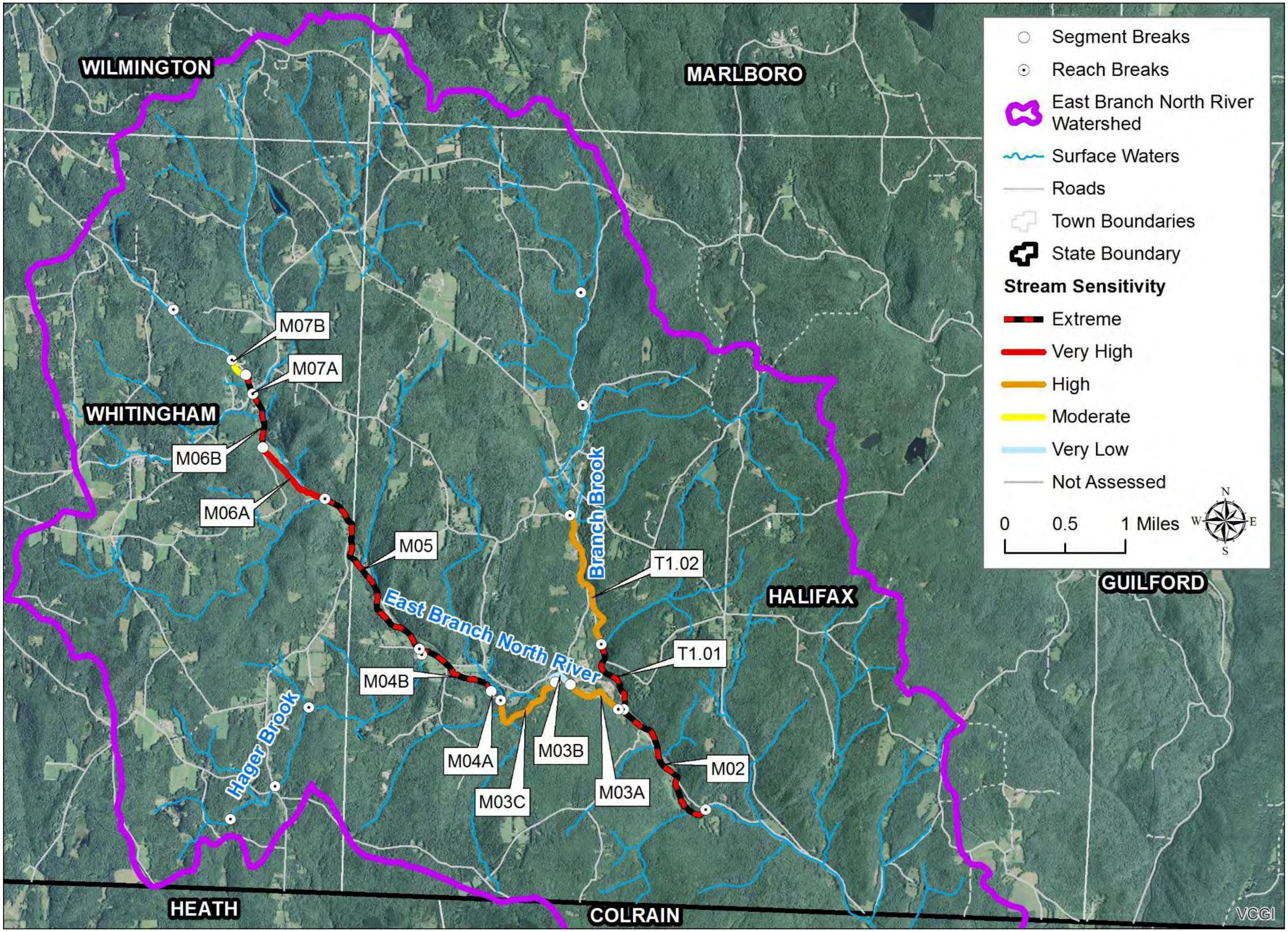


Figure 4.27: Stream Sensitivity Ratings for the East Branch North River study area.

5.0 Preliminary Project Identification

5.1 Watershed Level Opportunities

5.1.1 Stormwater Runoff

Increased stormwater runoff, even in less developed and rural areas of Vermont such as the Towns of Halifax and Whitingham, can increase peak flood flows and the erosive power of the streams. Stormwater runoff and the associated sediment loading from gravel roads is a primary management concern for rural watersheds like the East Branch North River. Increasing development results in more driveways and roads, which funnel sediment and runoff directly into streams. Sediment from roads and driveways can be addressed with improved drainage ditch networks, limiting future driveway lengths in sensitive areas, and other approaches. The Vermont Better Roads program provides assistance to towns seeking ways to reduce rural stormwater problems.

In the future, if development pressures heighten concerns about impacts from stormwater runoff, the towns in the watershed could consider enacting local standards and guidelines for stormwater treatment or mitigation. Alternatively, concerns about stormwater management can be raised during local development review as necessary. Local planning efforts are important to control and monitor stormwater and development impacts on natural resources. By planning proactively, towns can reduce long-term costs and risks associated with stormwater runoff. Options that the towns could consider at the local level include:

- Requiring stormwater controls for development projects which are not large enough in size to fall under state regulatory permits (less than 1 acre impervious cover), but likely have a measurable impact on the conditions of adjacent waterbodies (e.g., habitat, water quality).
- Encouraging low impact development and use of green stormwater infrastructure through development density incentives for projects with reduced impervious cover footprints.

Beginning in 2018, VTDEC will begin phasing in the Municipal Roads General Permit (MRGP), and towns will need to begin taking steps toward meeting the permit's requirements. The MRGP is intended to achieve significant reductions in stormwater-related erosion from municipal roads. Municipalities will be required to develop and implement a multi-year plan to stabilize road drainages to reduce erosion and meet water quality standards.

5.1.2 Flood Hazard Zones

<u>FEMA Mapped Floodplains</u>

Many Vermont communities found along rivers large and small have faced significant property losses and risks to public safety during past flood events. The East Branch North River watershed is a very flashy watershed due to its steep headwaters and soils with poor infiltration. The FEMA Flood Insurance Study (FIS) for the East Branch North River covers a small section through the Village of Jacksonville (M05-M07) and a portion of M02 near the Branch Brook confluence, with a non-detailed study. The lack of a detailed study through these sections and through the remainder of the watershed indicates that inundation hazards may be underestimated. We recommend that Halifax and Whitingham consider flood hazard ordinances that prevent encroachment in the entire 100-year floodplain (i.e., floodway and floodplain fringe) once detailed study information is available.

River Corridors

While inundation-related flood loss is a significant component of flood disasters, the predominant mode of damage during floods in Vermont is fluvial erosion. Towns can reduce flood recovery and infrastructure maintenance costs and increase public safety by limiting development in areas adjacent to rivers with a high potential for vertical and lateral adjustment. The statewide river corridor developed by VTDEC represents a useful "first-cut" mapping of the area a river or stream requires to redevelop or maintain equilibrium (i.e., least erosive) conditions over the long term. The statewide corridor is generated based on the meander belt width of the channel and includes an additional 50-foot buffer on each side. River corridor mapping can be improved with field survey data of existing channel morphology and valley walls, such as the data compiled for this project. Town zoning regulations based on the statewide or an improved river corridor map should be considered by the Towns of Halifax and Whitingham to better map flood and erosion risks for both the safety and protection of their citizens, and the infrastructure controlled by the municipality.

Halifax has implemented river corridor protection and qualifies for the maximum state aid (17.5%) from the Emergency Relief and Assistance Fund (ERAF) to cover future flood damages. The Town of Whitingham does not have an approved local hazard mitigation plan or river corridor protection ordinances. Whitingham is currently eligible for the minimum ERAF rate of 7.5% which can increase to 12.5% and 17.5% if the two respective measures are implemented. More information is available through VTDECs Flood Ready website (http://floodready.vermont.gov/).

5.1.3 Stream Crossings

Throughout Vermont, undersized and poorly aligned river crossings interrupt flood flows, sediment and woody debris movement downstream, and fish and wildlife migration. These conditions result in:
1) channel instability and/or damage to infrastructure and personal property; 2) increased flooding; 3) decreased fish and wildlife population health; and 4) degraded water quality. Many structures in the East Branch North River study area are currently undersized and causing various problems such as upstream sediment/debris deposition, excessive erosion, and limited aquatic organism passage (Tables 5.1 and 5.2). Undersized structures in the Village of Jacksonville caused significant volumes of floodwater to spill over the banks and flow down Routes 100 and 112. As such structures come up for replacement, resizing them to accommodate expected discharge and sediment loads and placing them in proper alignment with stream channe

Figure 5.1: Tropical Storm Irene floodwaters overtopping the culvert and bridge at the Whitingham Municipal Center and flowing south down VT 100 (photo courtesy of G. Havreluk).

Table 5.1: Summary of culvert data in the East Branch North River watershed.

Map ID	SGA Reach/Segment	Town	SGAID	Location	% Bankfull Width	Geomorphic Compatibility	Aquatic Organism Passage* (AOP)	AOP Retrofit Potential**
1	M07A	Whitingham	100000000613081	Whitingham Municipal Center	54	Mostly Compatible	Reduced	MML

*Notes on AOP
Green: Full AOP for all aquatic organisms
Gray: Reduced AOP for all aquatic organisms
Orange: No AOP for all aquatic organisms except adult salmonids
Red: No AOP for all aquatic organisms including adult salmonids

** Notes on AOP Retrofit Potential:
H: High probability the existing culvert can be retrofitted
M: Medium probability the existing culvert can be retrofitted
L: Low probability the existing culvert can be retrofitted
Position 1 (left): For strong swimmers
Position 2 (Center): For moderate swimmers
Position 3 (right): For weak swimmers

Table 5.2: Summary of Bridge Data in the East Branch North River Watershed.

Map ID #	SGA Reach/ Segment	Town	SGAID	Location	Material	Curve Channel Width (ft)	Structure Length (ft)	Structure Height (ft)	Structure Width (ft)	% Bankfull Width
1	M02	Halifax	200112000213082	VT 112	Steel	62.8	15	60	25	96
2	M02	Halifax	100001000213081	Branch Rd	Steel	62.8	34	15	35	56
3	M03A	Halifax	200112000013081	VT 112	Steel	52.1	15	60	70	134
4	M03C	Halifax	700000000113083	Halifax Falls Ln	Steel	52.1	20	16	64	122.8
5	M04B	Halifax	200112000313082	VT 112	Concrete	49.3	130	16	48	97
6	M05	Halifax	200112000413082	VT 112	Steel	42.9	50	6	65	152
7	M05	Whitingham	200112000513082	VT 112	Steel	42.9	55	10	50	117
8	M06A	Whitingham	200112000013211	VT 112	Steel	35.5	30	16	70	197
9	M06B	Whitingham	700000000013213	Private Footpath	Timber	35.5	8	5.5	26	73
10	M06B	Whitingham	200112000013212	VT 112	Steel	35.5	36	7	80	225
11	M06B	Whitingham	700000000113213	Private Driveway	Steel	35.5	20	5	30	85
12	M06B	Whitingham	700000000213213	Private Driveway	Steel	35.5	20	6.5	28	79
13	M06B	Whitingham	700000000313213	Private Driveway	Steel	35.5	20	5	26	73
14	M06B	Whitingham	700000000413213	Private Driveway	Steel	35.5	20	8	20	56
15	M07A	Whitingham	200100000413212	VT 100S	Concrete	15.6	90	5	6	39
16	M07A	Whitingham	400000000013211	Whitingham Municipal Center	Concrete	15.6	18	6.5	5.5	35
17	T1.02	Halifax	700000000213083	Private Driveway	Steel	32.3	14	10	32	99
18	T1.02	Halifax	100000000713081	Branch Road	Steel	32.3	30	8	44	136
19	T1.02	Halifax	700000000313083	Private Driveway	Steel	32.3	15	14	28	87
20	T1.02	Halifax	100000000813081	Sprague Rd	Concrete	32.3	25	12	22	68

5.2 Site-Level Project Opportunities

The site-level projects developed for the East Branch North River and the Branch Brook watersheds are provided for each Town in Tables 5.3 and 5.4. The project strategy, technical feasibility, and priority for each project are listed by project number and reach/segment. A total of 23 projects were identified to promote the restoration or protection of channel stability and aquatic habitat (Tables 5.3 and 5.4). These tables summarize key information for each project, including the site stressors and constraints, project strategy, priorities for hazard mitigation and ecological benefit, relative costs (i.e., low, moderate, and high), and potential partners and funding sources.

Tables 5.3 to 5.5 include a ranking of project priority, using our best professional judgment (and input from VTDEC, WRC, and other local stakeholders), of hazard mitigation and ecological benefits. Many river corridor restoration projects help mitigate flood and erosion hazards and improve the ecological conditions of the reach and watershed as a whole (e.g., improved habitat, protection of water quality, etc.). However, some project types provide a greater benefit to one over the other. While it is difficult to place a specific value on each project, rankings of “low,” “medium,” and “high” are intended to provide a means to compare the types of benefits each project provides relative to the others. A summary of what is meant by these two priority types is provided below.

> *Hazard Mitigation Priority:* refers to the potential for the project to mitigate flood and erosion hazards for the river corridor in the reach and in downstream areas. For example, replacing an undersized culvert with an appropriately sized structure could reduce flood/erosion hazards around the structure and downstream.
>
> *Ecological Benefits Priority:* refers to the potential for the project to improve aquatic habitat conditions and water quality in the reach and watershed. For example, a riparian buffer planting will improve habitat by increasing shading along the river and reducing long-term bank erosion.

The project locations for the study area are included on the maps provided in Appendix D. The 30 projects are further broken down by category as follows: twelve (13) active geomorphic restoration projects, ten (10) passive geomorphic restoration projects, and seven (7) infrastructure resiliency projects.

The 11 "high" priority projects along the East Branch North River and the one (1) “high” priority project along Branch Brook are described in greater detail in Appendix E. Additional project development summaries were provided for a subset of the high priority projects, included in Appendix F.

Seven (7) projects were identified to protect municipal, state, and private infrastructure, and are included in Appendix G. Note that the infrastructure resiliency projects were identified primarily for hazard mitigation purposes. These projects are not focused on improving channel dynamics or water quality, and thus they are not suitable for Vermont State Clean Water Initiative funding.

5.2.1 *Town of Halifax River Corridor Project Opportunities*

Table 5.3: Site-Level Project Identification for the East Branch North River and Branch Brook in the Town of Halifax, Vermont.

Project ID, Location, Reach, Lat/Long	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Potential Partners & Funding
NR-1 VT 112 Reach M02 42.74759 N -72.75209 W	Passive Restoration Buffer Planting and Corridor Protection	A large floodchute and floodplain along the west bank of the river provided important floodwater and debris storage during T.S. Irene. The steep valley wall is eroding and near vertical with no woody vegetation along the edge of the hayfield.	Plant woody vegetation along the top of the hayfield to create a buffer at least 50ft wide. Planting designs should account for continuing bank migration. Protect corridor from future development.	Low	Moderate	Reduce sediment inputs to the channel	Low	Private Landowner, WCNRCD Trees for Streams
NR-2 VT 112 at Branch Brook Rd Reach M02 42.75767 N -72.75927 W	Passive Restoration Corridor Protection	The confluence of Branch Brook with the EB North River creates an alluvial fan setting that distributes large volumes of sediment and debris across the floodplain along the north bank.	Protect the floodplain from future development and ensure that flood recovery efforts do not reduce accessibility of floodplain	High	Moderate	Protect important floodplain	Low	Private Landowner, VTANR ERP
NR-3 Branch Brook Rd Reach M02 42.7583 N -72.76141 W	Active Restoration Bridge Retrofit/ Replacement	The Branch Brook Rd bridge is a major bankfull width constriction (56%) leading to moderate scour along both abutments and increased risk of debris catchment during floods.	Consider replacing the bridge with a larger structure when it is up for replacement. Investigate opportunities to reconfigure the abutments to increase width and improve sediment and debris transport, and conveyance of flood waters through the reach.	Moderate	Low	Reduced risk of debris or sediment accumulation at bridge during a storm event, improve sediment transport through reach.	High	Town of Halifax
NR-5 Halifax Falls Ln Segment M03.C 42.7599 N -72.77384 W	Active Restoration Stormwater Treatment and Gully Stabilization	New development along Halifax Falls Ln appears to be concentrating runoff into an existing gully that drains to a mass failure. Increased runoff from the ongoing development may exacerbate the gully and mass failure.	Inspect the drainage systems and implement stormwater treatment practices to reduce and/or redirect the runoff away from the gully and mass failure.	Moderate	Moderate	Reduce sediment sources to stream	Moderate	Private Landowner, VTANR ERP

Table 5.3: Site-Level Project Identification for the East Branch North River and Branch Brook in the Town of Halifax, Vermont.

Project ID, Location, Reach, Lat/Long	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Potential Partners & Funding
NR-6 Halifax Falls Ln Segment M03.C 42.7599 N -72.77509 W	Passive Restoration Corridor Protection	An approximately 3-acre forested floodplain that received a large volume of sediment and debris during T.S. Irene upstream of Halifax Falls.	Protect the forested floodplain from future development.	Moderate	Low	Protect floodplain area from future development.	Low	Private Landowner, VTANR ERP; VLT; VRC
NR-7 Neubert Property Segments M04.A/M04.B 42.76047 N -72.78196 W	Passive Restoration Corridor Protection	Approximately 5 acres of forested floodplain on both sides of the channel received huge volumes of sediment and debris during T.S. Irene. Some channel dredging activities following the flood piled spoils and dredged material within the floodplain, however there still appears to be full access. Beaver ponds and other features provide wildlife habitat.	Protect the two floodplain areas from future development and assess if the dredging spoils should be moved to improved access.	High	Moderate	Protect floodplain area from future development and from flood recovery efforts that might reduce floodplain access and function.	Low	Private Landowners, VTANR ERP; VLT; VRC
NR-8 Neubert Property Segment M04.B 42.76164 N -72.78323 W	Passive Restoration Buffer Planting	Approximately 500ft of the north bank is lacking native woody vegetation. The bank is somewhat unstable.	Plant the top of the bank to establish a 50ft wide buffer of native woody plants.	Moderate	High	Vegetation will stabilize the bank reducing sediment inputs to the channel. LWD inputs will help the channel aggrade increasing access to the large adjacent floodplains.	Low/Moderate	Private Landowner, VTANR ERP, WCNRCD
NR-9 Betit Property Segment M04.B 42.76314 N -72.78872 W	Active and Passive Restoration Berm Removal and Buffer Planting	Several berms were constructed following T.S. Irene with dredged materials and with spoils removed from floodplains along the north bank. These berms are now densely vegetated with invasive knotweed.	Remove all berms that are not protecting structures on the property and plant with native woody vegetation.	Moderate	High	Restore access to a 20-40ft wide floodplain bench and establish native woody vegetation to provide shade and habitat for the channel.	Moderate/High	Private Landowner, VTANR ERP, WCNRCD

Table 5.3: Site-Level Project Identification for the East Branch North River and Branch Brook in the Town of Halifax, Vermont.

Project ID, Location, Reach, Lat/Long	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Potential Partners & Funding
NR-10 VT 112 Reach M05 42.77163 N -72.80161 W	Passive Restoration Corridor Protection	Very important 8-10 acre forested floodplain that provided critical storage of floodwaters and debris during T.S. Irene. Numerous flood chutes and wetland areas are located throughout.	Protect the floodplain area from future development	High	High	Conserve an important forested floodplain with associated wetland and beaver pond habitats.	Low/Moderate	Private Landowner, VRC, VLT, VTANR ERP
BB-1 Branch Brook Rd Reach T1.01 42.75956 N -72.76098 W	Passive Restoration Corridor Protection	The highly active channel from the Town Garage driveway downstream to the confluence has numerous flood chutes and small floodplain areas that should be protected. This project could combine with NR-2.	Protect the floodplain areas from future development.	Moderate	Low	Protect floodplains that provide important storage areas for floodwaters and sediment immediately upstream of the confluence with the EB North River	Low	Private Landowner, VTANR ER; VLT; VRCP
BB-4 Driveway Reach T1.02 42.76665 N -72.76465 W	Active Restoration Bridge Retrofit	The stone armor protecting the concrete block abutments represent a bankfull constriction (67%)	Pull the abutment armor slopes back or replace with a stacked stone wall to remove bankfull channel constriction.	Moderate	Low	Remove bankfull constriction and reduce risk of erosion or scour at the bridge.	Moderate	Private Landowner
BB-5 Branch Brook Rd Reach T1.02 42.76779 N -72.76535 W	Active Restoration Stormwater Inputs	Several stormwater inputs along Branch Brook road have unstable outlets and are contributing excess sediment to the stream. Runoff from the steep sections of gravel road and associated ditches is also a significant sediment source.	Assess the stability of culvert outlets and ditches for erosion. Add stone armor where appropriate to stabilize ditches and culvert outlets.	Low	Moderate	Reduce sediment inputs to the channel.	Moderate	Town of Halifax, Better Roads, MRGP
BB-7 Sumner Farm Reach T1.02 42.7757 N -72.76783 W	Active Restoration Cattle Stream Access	Cattle have created several water access points to the stream channel, some are moderately eroded.	Create at least 2 stabilized water access points for cattle, and fence the remaining stream bank.	Low	Moderate	Reduce sediment and nutrient inputs to the channel and preserve water access for cattle.	Low	Private Landowner, VTANR ERP, NRCS EQIP, WCNRCD

Table 5.3: Site-Level Project Identification for the East Branch North River and Branch Brook in the Town of Halifax, Vermont.

Project ID, Location, Reach, Lat/Long	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Potential Partners & Funding
BB-8 Sumner Farm Reach T1.02 42.77608 N -72.7677 W	Passive Restoration Buffer Planting	Two areas of pasture have no woody buffer vegetation (400LF and 500LF) along the west bank of Branch Brook.	Plant a woody vegetated buffer at least 25ft wide and protect the plantings and the channel from cattle grazing with an electric fence. Should be carried out with cattle water access in Project BB-7.	Low	High	Establish woody vegetation along the bank to provide shading and woody debris inputs to the channel.	Low	Private Landowner, VTANR ERP, WCNRCD Trees for Streams; NRCS EQIP

5.2.2 *Town of Whitingham River Corridor Project Opportunities*

Table 5.4: Site-Level Project Identification for the East Branch North River in the Town of Whitingham, Vermont.

Project ID, Location, Reach, Lat/Long	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Potential Partners & Funding
NR-12 VT 112 Reach M06.A 42.78783 N -72.81725 W	Active Restoration Berm Removal & Buffer Planting	A 250ft long and roughly 3ft tall historic berm is reducing access to a mowed floodplain along VT 112 extending down to the wastewater plant. T.S. Irene floodwaters accessed the floodplain downstream of the berm	Assess the accessibility of the floodplain downstream of the berm to see if berm removal is beneficial, if so, remove the berm. Buffer plantings could be incorporated into the floodplain area.	Moderate	Low	Improve accessibility to a relatively large floodplain.	Low to Moderate	Private Landowner, VTANR ERP, WCNRCD Trees for Streams
NR-13 First Stop Convenience Store Segment M06.B 42.79314 N -72.8201 W	Active Restoration Floodplain Restoration and Infrastructure Resiliency	The channel is narrow and deeply incised as it flows past the First Stop convenience store and several commercial buildings before crossing under VT 112. The floodplain across the channel from the gas station was accessed during T.S. Irene and is slightly lower in elevation., but has large Irene sediment deposits The existing bank armor appears undersized.	Reshape the east bank to lower the elevation of the floodplain to increase accessibility and attenuate flood flows and sediment. Replace the existing bank armor with a stacked stone wall to increase slope protection and increase bankfull width. Follow guidance in VTANR Standard River Management Principles and Practices.	High	Moderate	Improve accessibility to a medium-sized floodplain. Protect gas station and convenience store from erosion hazard and reduce inundation risk	Moderate	Private Landowner (stabilization project), VTANR ERP (floodplain reconnection project)
NR-15 VT 112 Segment M06.B 42.79562 N -72.82126 W	Passive Restoration Buffer Planting	The stacked stone wall and parking area along VT 112 have no woody vegetation to shade the channel.	Plant willow cuttings along the base and the top of the stone wall where possible. Additional plantings could be installed along the edge of the parking area, requiring some excavation and topsoil.	Low	Moderate	Increase channel shading, improve aesthetics, provide some opportunity for stormwater treatment.	Low	VTANR ERP, WCNRCD Trees for Streams
NR-16 Floodplain Reconnection and Driveway Bridge Segment M06.B 42.79619 N -72.82157 W	Active Restoration Berm Removal and Bridge Replacement	The steel driveway bridge located at the confluence of the EB North River and the Gates Pond drainage is undersized (55% wbkf). A large cobble berm along the east bank of Gates Pond Outlet restricts access to the floodplain immediately upstream of the confluence.	Replace the bridge with a larger structure. Remove portions of the cobble berm to allow floodplain access during large flow events. The driveway may require additional stabilization to reduce damage during floods.	High	Low	Improve conveyance of floodwaters, sediment, and debris through downtown Jacksonville.	High	Private Landowner, VTANR ERP

Table 5.4: Site-Level Project Identification for the East Branch North River in the Town of Whitingham, Vermont.

Project ID, Location, Reach, Lat/Long	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Potential Partners & Funding
NR-17 VT 100 and VT 112 Segment M07.A 42.79677 N 72.82193 W	Active Restoration Bridge Replacement	The 90-foot long crossing under the intersection of VT 100 and VT 112 in downtown Jacksonville is severely undersized. The bridge and downstream channel have an approximate width of only 6ft, or 38% of bankfull width. Electric conduits on the downstream end of the bridge are exposed and could catch debris.	Replace the bridge with a larger structure when it is up for replacement. The downstream channel should also be enlarged to match the capacity of the bridge.	High	Low	Increase capacity of the bridge to reduce flood risk.	Very High	VTRANS, Town of Whitingham, Private Landowner
NR-18 Whitingham Municipal Center Segment M07.A 42.79843 N -72.82262 W	Active Restoration Culvert Replacement	The 8.5ft wide squash CMP culvert under the southern entrance to the municipal center is a significant bankfull width constriction at 53% and the culvert is in poor condition. However, the upstream and downstream bridges have significantly lower capacity.	Replace with a larger structure when this culvert comes up for replacement. Investigate the option for consolidating the two entrances to the municipal building and only having one bridge.	High	Moderate	Increase capacity of crossing to reduce flood risk.	High	Town of Whitingham; VTrans
NR-19 Whitingham Municipal Center Segment M07.A 42.79855 N -72.82271 W	Active Restoration Bridge Replacement/ Removal	The concrete bridge at the northern entrance to the municipal center is an extreme bankfull constriction (34%) and was the location of major overbank flooding during T.S. Irene.	Replace with a larger structure. Consider removing the bridge and replacing the downstream culvert (Project NR-18) with a larger bridge or culvert. Any increases in structure capacity need to consider the downstream channel and bridge capacity under VT 100 and VT 112.	High	Low	Increase capacity of crossing to reduce flood risk	High	Town of Whitingham; VTrans
NR-20 VT 100 Segment M07.B 42.7993 N -72.82439 W	Passive Restoration Corridor Protection	The forested floodplain upstream of the Whitingham Municipal Center provides important storage capacity for floodwaters before they reach the developed corridor. The channel is slightly incised and lacks large substrate and LWD to encourage bed aggradation.	Protect the floodplain from future development and consider the installation of bed roughening structures (large boulders or LWD tied in to the banks) to encourage bed aggradation and increase floodplain accessibility.	Moderate	Moderate	Protect an important floodplain area from future development.	Low to Moderate	VTANR ERP, Private Landowners; VLT; VRC

Table 5.4: Site-Level Project Identification for the East Branch North River in the Town of Whitingham, Vermont.

Project ID, Location, Reach, Lat/Long	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Potential Partners & Funding
NR-21 White House in Jacksonville Segment M07.A 42.79792 N -72.82255 W	Active Restoration Floodplain Restoration	Downstream of the town offices and fire department, the East Branch of the North River passes underneath a house. The opening at the house is a bankfull constriction (45%) and was filled with sediment and debris following T.S. Irene. The adjacent lawn is elevated and restricts access to the downstream floodplain.	The section of the house over the channel could be removed. The backyard of the house is sloped, potentially from fill used in the construction of the municipal complex. This filled area could be excavated to allow floodwaters to access the adjacent floodplain.	High	Low	Protect house and upstream areas from damage due to flooding or debris snagging and increase floodplain area and access to existing floodplain.	Moderate	Private Landowner, FEMA

5.2.3 High Priority Project Selection for Project Packets

The corridor planning partners reviewed and commented on the list of preliminary projects during a watershed tour in August 2017, and via email. From the list of 30 projects, a subset of 13 high-priority projects summarized in Appendix E were discussed for further development. Five (5) project areas from the list of high-priority projects were chosen for further development. One (1) of the projects selected for further development is located in Halifax. The remaining four (4) projects were included in an alternatives analysis for improving flood resiliency within the Village of Jacksonville. Project summaries are included in Appendix F for the five highest priority project bundles. Each summary includes:

- A description of the site location and river reach
- A brief technical summary of the stressors on channel stability and aquatic habitat
- A description of channel and floodplain restoration alternatives
- Preliminary cost opinions for restoration alternatives
- A list of current and potential technical partners and funding
- A review of regulatory requirements

6.0 Conclusions and Recommendations

Tropical Storm Irene in 2011 was a major flood in the North River watershed and caused widespread damage along the East Branch, especially in the Village of Jacksonville. Flooding and erosion problems are best addressed through a comprehensive approach to understand how reach and watershed-scale stressors cause channel instability, degraded water quality, and impacts to aquatic habitat. The information in this plan is intended to assist local, regional, state, and federal partners and stakeholders in planning and project development to address water quality and flood resiliency concerns in the Towns of Halifax and Whitingham. While several of the projects identified in this report address infrastructure resiliency specifically, most of the projects would have benefits for both water quality and hazard mitigation.

Below are some key water quality planning and flood resiliency recommendations for the entire North River study area, and specific recommendations for the Towns of Halifax and Whitingham.

<u>East Branch North River Watershed</u>

Based on the damage incurred in the 2011 and the 2017 floods, as well as other historic floods, the North River watershed is vulnerable to severe flooding during prolonged rainstorms (i.e., Tropical Storm Irene) and intense thunderstorms. The East Branch North River watershed is a particularly flashy watershed due to its steep headwaters and soils with poor infiltration. Given the inherent flooding and erosion risks in the watershed, we recommend the Towns of Halifax and Whitingham consider the actions listed below to improve the protection of life and property.

- The FEMA Flood Insurance Study (FIS) for the East Branch North River does not include any areas of detailed study (i.e., base flood elevations determined). The FIS covers a small section through the Village of Jacksonville (M05-M07) and a portion of Reach M02 near the Branch Brook confluence with less accurate "Zone A" mapping. The lack of a detailed study through these sections and through the remainder of the watershed indicates that inundation hazards are likely underestimated. We recommend that Halifax and Whitingham consider flood hazard ordinances that prevent encroachment in the entire 100-year floodplain (i.e., floodway and floodplain fringe) once detailed study information is available from FEMA.
- River Corridor protection ordinances were incorporated into the Town of Halifax Zoning Regulations in 2016. River corridor protection ordinances should also be considered by the Whitingham to better map flood and erosion risks for both the safety and protection of their citizens, and the infrastructure controlled by the municipality.
- The current Emergency Relief and Assistance Fund (ERAF) rate for state aid to cover flood damage costs in Whitingham is 7.5%. Whitingham does not have an approved Local Hazard Mitigation Plan or River Corridor Protection. If these two actions were implemented, the ERAF rate would increase to the maximum of 17.5% for both towns. The Town of Halifax has the maximum ERAF rate of 17.5% as all five measures have been implemented, including river corridor protection zoning.
- The floodplains and river corridors of the East Branch North River in Halifax and Whitingham have been significantly encroached upon by roads and buildings, leaving few locations with fully intact and functioning riparian areas. The fact that such a high percentage of the river corridor is impacted by human development makes the few remaining areas of intact corridor highly valuable for flood mitigation. In this report we identify several important floodplains/river corridors that provide disproportionately high ecosystem services in the way of downstream flood protection. While mapped wetlands and floodplains may prevent encroachment into some of these priority areas, we recommend that conservation easements be pursued to limit further loss of functioning floodplain in the watershed.

<u>Town of Halifax</u>

- Below are some summary observations for the East Branch North River in Halifax:
    - Channel stability and aquatic habitat were generally fair in most reaches, mainly due to historic encroachment from VT 112 and other town roads on the river corridor.
    - More functioning floodplains and river corridors were found upstream of Halifax Falls where the river valley is naturally less confined and the river has more freedom to meander due to less road encroachment.
- Below are some summary observations for Branch Brook in Halifax:
    - Channel stability and aquatic habitat was generally fair to good in most reaches, with impacts mainly from to historic encroachment from Branch Road on the river corridor.
    - The channel is confined by its valley and has coarse substrate (i.e., cobbles and boulders) in the bed and banks. These characteristics likely make Branch Brook more resilient to floods in terms of channel stability and maintenance of healthy aquatic habitat.

- Most of the bridges and culverts we assessed in Halifax were generally compatible with channel stability as a function of their opening width relative to the bankfull channel width. There are a few municipal structures that are undersized and may be more vulnerable to damage in future floods. The summary of structures in this report, including the reference bankfull channel width listed for each one, provides a means for the Town to understand the relative flood vulnerability and prioritize structure replacements with these criteria in mind.

Town of Whitingham

- Below are some summary observations for the East Branch North River in Whitingham:
    - Channel stability and aquatic habitat were generally fair in most reaches, mainly due to historic encroachment from buildings, state highways, and town roads on the river corridor.
    - One small area of functioning floodplain and river corridor was noted upstream of Jacksonville, but it is limited to an area where buildings and VT 100 do not encroach on the channel. Upstream (north) of this area VT 100 is again situated right next to the river, with the road and embankments occupying historic floodplain.
    - Historic river encroachment is especially severe in the Village of Jacksonville, resulting in elevated flood and erosion risks for many properties and roads. Our more detailed work to understand flood risks and opportunities for mitigation, summarized in Appendix F, provides an evaluation of the costs and benefits of several alternatives in the Village. The high priority alternatives are intended to address concerns related to flood risks, channel instability, and aquatic habitat restoration in this highly impacts area. From our alternatives analysis, we feel the two most important actions that could be taken to address these concerns are:
        - Remove the severely undersized bridge providing one of two access points to the municipal center.
        - Replace the severely undersized state highway bridge (VT 100/112) with a bankfull structure (16 feet wide).
- Many of the municipal and private bridges and culverts we assessed in Whitingham were not compatible with channel stability as a function of their opening width relative to the bankfull channel width. The summary of structures in this report, including the reference bankfull channel width listed for each one, provides a means for the Town to understand the relative flood vulnerability and prioritize structure replacements with these criteria in mind.

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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, 2007, Vermont Agency of Natural Resources, Waterbury, VT http://www.anr.state.vt.us/dec/waterq/rivers/htm/rv_geoassesspro.htm

Acre -- A measure of area equal to 43,560 ft^2 (4,046.87 m^2). One square mile equals 640 acres.

Adjustment process --or 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 stream discharge and/or bed-load characteristics are changing. Opposite of degradation.

Algae -- Microscopic plants that grow in sunlit water containing phosphates, nitrates, and other nutrients. Algae, like all aquatic plants, add oxygen to the water and are important in the fish food chain.

Alluvial -- Deposited by running water.

Alluvium -- A general term for detrital deposits make by streams on riverbeds, floodplains, and alluvial fans; esp. a deposit of silt or silty clay laid down during time of flood. The term applies to stream deposits of recent time. It does not include subaqueous sediments of seas or lakes.

Anadromous -- Pertaining to fish that spend a part of their life cycle in the sea and return to freshwater streams to spawn.

Aquatic ecosystem -- Any body of water, such as a stream, lake, or estuary, and all organisms and nonliving components within it, functioning as a natural system.

Armoring -- A natural process where an erosion-resistant layer of relatively large particles is established on the surface of the streambed through removal of finer particles by stream flow. A properly armored streambed generally resists movement of bed material at discharges up to approximately 3/4 bank-full depth. Augmentation (of stream flow) – Increasing flow under normal conditions, by releasing storage water from reservoirs.

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

Backwater -- (1) A small, generally shallow body of water attached to the main channel, with little or no current of its own, or (2) A condition in subcritical flow where the water surface elevation is raised by downstream flow impediments.

Backwater pool -- A pool that formed as a result of an obstruction like a large tree, weir, dam, or boulder.

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 bank-full discharge.

Bankfull channel width -- The top surface width of a stream channel when flowing at a bank-full 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.

Bankfull width -- The width of a river or stream channel between the highest banks on either side of a stream.

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 overwide channel.

Barrier -- A physical block or impediment to the movement or migration of fish, such as a waterfall (natural barrier) or a dam (man-made barrier).

Base flow -- The sustained portion of stream discharge that is drawn from natural storage sources, and not affected by human activity or regulation.

Bed load -- Sediment moving on or near the streambed and transported by jumping, rolling, or sliding on the bed layer of a stream. See also suspended load.

Bed material -- The sediment mixture that a streambed is composed of.

Bed material load -- That portion of the total sediment load with sediments of a size found in the streambed.

Bed roughness -- A measure of the irregularity of the streambed as it contributes to flow resistance. Commonly expressed as a Manning "n" value.

Bed slope -- The inclination of the channel bottom, measured as the elevation drop per unit length of channel.

Bedform -- Individual patterns which streams follow that characterize the condition of the stream bed into several categories. (*See*: braided, dune-ripple, plane bed, riffle-pool, step-pool, and cascade)

Benthic invertebrates -- Aquatic animals without backbones that dwell on or in the bottom sediments of fresh or salt water. Examples: clams, crayfish, and a wide variety of worms.

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.

Biota -- All living organisms of a region, as in a stream or other body of water.

Boulder -- A large substrate particle that is larger than cobble, between 10 and 160 inches in diameter.

Boundary resistance -- The ability a stream bank has to withstand the erosional forces of the flowing water at varying intensities. Under natural conditions boundary resistance is increased due to stream bank vegetation (roots), cohesive clays, large boulder substrate, etc.

Braided -- A stream channel characterized by flow within several channels, which successively meet and divide. Braiding often occurs when sediment loading is too large to be carried by a single channel.

Braiding (of river channels) -- Successive division and rejoining of riverflow with accompanying islands.

Buffer strip -- A barrier of permanent vegetation, either forest or other vegetation, between waterways and land uses such as agriculture or urban development, designed to intercept and filter out pollution before it reaches the surface water resource.

Canopy -- A layer of foliage in a forest stand. This most often refers to the uppermost layer of foliage, but it can be used to describe lower layers in a multistoried stand. Leaves, branches and vegetation that are above ground and/or water that provide shade and cover for fish and wildlife.

Cascade -- A short, steep drop in streambed elevation often marked by boulders and agitated white water.

Catchment -- (1) The catching or collecting of water, especially rainfall. (2) A reservoir or other basin for catching water. (3) The water thus caught. (4) A watershed.

Channel -- An area that contains continuously or periodically flowing water that is confined by banks and a streambed.

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

Channel evolution model (CEM) -- A series of stages used to describe the erosional or depositional processes that occur within a stream or river in order to regain a dynamic equilibrium following a disturbance.

Clay -- Substrate particles that are smaller than silt and generally less than 0.0001 inches in diameter.

Coarse gravel -- Substrate that is smaller than cobble, but larger than fine gravel. The diameter of this stream-bottom particulate is between 0.63 and 2.5 inches.

Cobble -- Substrate particles that are smaller than boulders and larger than gravels, and are generally between 2.5 and 10 inches in diameter.

Confinement -- *see* Valley confinement

Confluence -- (1) The act of flowing together; the meeting or junction of two or more streams; also, the place where these streams meet. (2) The stream or body of water formed by the junction of two or more streams; a combined flood.

Conifer -- A tree belonging to the order Gymnospermae, comprising a wide range of trees that are mostly evergreens. Conifers bear cones (hence, coniferous) and have needle-shaped or scalelike leaves.

Conservation -- The process or means of achieving recovery of viable populations.

Contiguous habitat -- Habitat suitable to support the life needs of a species that is distributed continuously or nearly continuously across the landscape.

Cover -- “cover” is the general term used to describe any structure that provides refuge for fish, reptiles or amphibians. These animals seek cover to hide from predators, to avoid warm water temperatures, and to rest, by avoiding higher velocity water. These animals come in all sizes, so even cobbles on the stream bottom that are not sedimented in with fine sands and silt can serve as cover for small fish and salamanders. Larger fish and reptiles often use large boulders, undercut banks, submerged logs, and snags for cover.

Critical shear stress -- The minimum amount of shear stress exerted by stream currents required to initiate soil particle motion. Because gravity also contributes to streambank particle movement but not on streambeds, critical shear stress along streambanks is less than for streambeds.]

Cross-section -- A series of measurements, relative to bankfull, that are taken across a stream channel that are representative of the geomorphic condition and stream type of the reach.

Crown -- The upper part of a tree or other woody plant that carries the main system of branches and the foliage.

Crown cover -- The degree to which the crowns of trees are nearing general contact with one another.

Cubic feet per second (cfs) -- A unit used to measure water flow. One cubic foot per second is equal to 449 gallons per minute.

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

Debris flow -- A rapidly moving mass of rock fragments, soil, and mud, with more than half of the particles being larger than sand size.

Deciduous -- Trees and plants that shed their leaves at the end of the growing season.

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.

Detritus -- is organic material, such as leaves, twigs, and other dead plant matter, that collects on the stream bottom. It may occur in clumps, such as leaf packs at the bottom of a pool, or as single pieces, such as a fallen tree branch.

Dike -- (1) (Engineering) An embankment to confine or control water, especially one built along the banks of a river to prevent overflow of lowlands; a levee. (2) A low wall that can act as a barrier to prevent a spill from spreading. (3) (Geology) A tabular body of igneous (formed by volcanic action) rock that cuts across the structure of adjacent rocks or cuts massive rocks.

Dissolved oxygen (DO) -- The amount of free (not chemically combined) oxygen dissolved in water, wastewater, or other liquid, usually expressed in milligrams per liter, parts per million, or percent of saturation.

Ditch -- A long narrow trench or furrow dug in the ground, as for irrigation, drainage, or a boundary line.

Drainage area -- The total surface area upstream of a point on a stream that drains toward that point. Not to be confused with watershed. The drainage area may include one or more watersheds.

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.

Dune-ripple -- A bedform associated with low-gradient, sand-bed channels; the low gradient nature of the channel causes the sand to form a sequence of dunes and small ripples; significant sediment transport typically occurs at most stream stages.

Ecology -- The study of the interrelationships of living organisms to one another and to their surroundings.

Ecosystem -- Recognizable, relatively homogeneous units, including the organisms they contain, their environment, and all the interactions among them.

Embankment -- An artificial deposit of material that is raised above the natural surface of the land and used to contain, divert, or store water, support roads or railways, or for other similar purposes.

Embeddedness -- is a measure of the amount of surface area of cobbles, boulders, snags and other stream bottom structures that is covered with sand and silt. An embedded streambed may be packed hard with sand and silt such that rocks in the stream bottom are difficult or impossible to pick up. The spaces between the rocks are filled with fine sediments, leaving little room for fish, amphibians, and bugs to use the structures for cover, resting, spawning, and feeding. A streambed that is not embedded has loose rocks that are easily removed from the stream bottom, and may even “roll” on one another when you walk on them.

Entrenchment ratio --The width of the flood-prone area divided by the bankfull width.

Epifaunal – “epi” means surface, and “fauna” means animals. Thus, “epifaunal substrate” is structures in the stream (on the stream bed) that provide surfaces on which animals can live. In this case, the animals are aquatic invertebrates (such as aquatic insects and other “bugs”). These bugs live on or under cobbles, boulders, logs, and snags, and the many cracks and crevices found in these structures. In general, older decaying logs are better suited for bugs to live on/in than newly fallen “green” logs and trees.

Ephemeral streams -- Streams that flow only in direct response to precipitation and whose channel is at all times above the water table.

Equilibrium Condition -- The state of a river reach in which the upstream input of energy (flow of water) and materials (sediment and debris) is equal to its output to downstream reaches. Natural river reaches without human impacts tend towards a “stable” state where predictable channel forms are maintained over the long term under varying flow conditions.

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.

Eutrophic -- Usually refers to a nutrient-enriched, highly productive body of water.

Eutrophication -- The process of enrichment of water bodies by nutrients.

Fine gravel -- Is substrate which is larger than sand, but smaller than coarse gravel. It is between 0.08 and 0.63 inches in diameter.

Flash flood -- A sudden flood of great volume, usually caused by a heavy rain. Also, a flood that crests in a short length of time and is often characterized by high velocity flows.

Floodplain -- Land built of fine particulate organic matter and small substrate that is regularly covered with water as a result of the flooding of a nearby stream.

Floodplain (100-year) -- The area adjacent to a stream that is on average inundated once a century.

Floodplain Function – Flood water access of floodplain which effects the velocity, depth, and slope (stream power) of the flood flow thereby influencing the sediment transport characteristics of the flood (i.e., loss of floodplain access and function may lead to higher stream power and erosion during flood).

Flow -- The amount of water passing a particular point in a stream or river, usually expressed in cubic feet per second (cfs).

Fluvial -- Migrating between main rivers and tributaries. Of or pertaining to streams or rivers.

Fluvial Geomorphology—The study of how rivers and their landforms interact over time through different climatic conditions.

Ford -- A shallow place in a body of water, such as a river, where one can cross by walking or riding on an animal or in a vehicle.

Fry -- A recently hatched fish.

Gabion -- A wire basket or cage that is filled with gravel or cobble and generally used to stabilize streambanks.

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

Gallons per minute (gpm) -- A unit used to measure water flow.

Geographic information system (GIS) -- A computer system capable of storing and manipulating spatial data.

Geomorphology -- A branch of both physiography and geology that deals with the form of the earth, the general configuration of its surface, and the changes that take place due to erosion of the primary elements and the buildup of erosional debris.

Glide -- A section of stream that has little or no turbulence.

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.

Grass/forb -- Herbaceous vegetation.

Gravel -- An unconsolidated natural accumulation of rounded rock fragments, mostly of particles larger than sand (diameter greater than 2 mm), such as boulders, cobbles, pebbles, granules, or any combination of these.

Groundwater -- Subsurface water and underground streams that can be collected with wells, or that flow naturally to the earth's surface through springs.

Groundwater basin -- A groundwater reservoir, defined by an overlying land surface and the underlying aquifers that contain water stored in the reservoir. In some cases, the boundaries of successively deeper aquifers may differ and make it difficult to define the limits of the basin.

Groundwater recharge -- Increases in groundwater storage by natural conditions or by human activity. See also artificial recharge.

Groundwater Table -- The upper surface of the zone of saturation, except where the surface is formed by an impermeable body.

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

Habitat diversity -- The number of different types of habitat within a given area.

Habitat fragmentation -- The breaking up of habitat into discrete islands through modification or conversion of habitat by management activities.

Headcut -- A sharp change in slope, almost vertical, where the streambed is being eroded from downstream to upstream.

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

High gradient streams -- typically appear as steep cascading streams, step/pool streams, or streams that exhibit riffle/pool sequences. Most of the streams in Vermont are high gradient streams.

Hydraulic gradient -- The slope of the water surface. See also streambed gradient.

Hydraulic radius -- The cross-sectional area of a stream divided by the wetted perimeter.

Hydric -- oil that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper horizon.

Hydrograph -- A curve showing stream discharge over time.

Hydrologic balance -- An accounting of all water inflow to, water outflow from, and changes in water storage within a hydrologic unit over a specified period of time. Hydrologic region -- A study area, consisting of one or more planning subareas, that has a common hydrologic character.

Hydrologic unit Code (HUC) -- A distinct watershed or river basin defined by an 8-digit code.

Hydrology -- The scientific study of the water of the earth, its occurrence, circulation and distribution, its chemical and physical properties, and its interaction with its environment, including its relationship to living things.

Hyporheic zone -- The area under the stream channel and floodplain where groundwater and the surface waters of the stream are exchanged freely.

Impoundment -- An area where the natural flow of the river has been disrupted by the presence of human-made or natural structure (e.g. weir or beaver dam). The impoundment backwater extends upstream causing sediment to be deposited on the stream bottom.

Improved paths – Paths that are maintained and typically involve paved, gravel or macadam surfaces.

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.

Incision ratio -- The low bank height divided by the bankfull maximum depth.

Infiltration (soil) -- The movement of water through the soil surface into the soil. Inflow

-- Water that flows into a stream, lake, Instream cover -- The layers of vegetation, like trees, shrubs, and overhanging vegetation, that are in the stream or immediately adjacent to the wetted channel.

Instream flows -- (1) Portion of a flood flow that is contained by the channel. (2) A minimum flow requirement to maintain ecological health in a stream.

Instream use -- Use of water that does not require diversion from its natural watercourse. For example, the use of water for navigation, recreation, fish and wildlife, aesthetics, and scenic enjoyment.

Intermittent stream -- Any nonpermanent flowing drainage feature having a definable channel and evidence of scour or deposition. This includes what are sometimes referred to as ephemeral streams if they meet these two criteria.

Irrigation diversion -- Generally, a ditch or channel that deflects water from a stream channel for irrigation purposes.

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

Kame – a deposit of stratified glacial drift in isolated mounds or steep-sided hills.

Lake -- An inland body of standing water deeper than a pond, an expanded part of a river, a reservoir behind a dam

Landslide -- A movement of earth mass down a steep slope.

Large woody debris (LWD) -- Pieces of wood at least 6 ft. long and 1 ft. in diameter (at the large end) contained, at least partially, within the bankfull area of a channel.

Levee -- An embankment constructed to prevent a river from overflowing (flooding).

Limiting factor -- A requirement such as food, cover, or another physical, chemical, or biological factor that is in shortest supply with respect to all resources necessary to sustain life and thus "limits" the size or retards production of a population.

Low gradient -- streams typically appear slow moving and winding, and have poorly defined riffles and pools.

Macroinvertebrate -- Invertebrates visible to the naked eye, such as insect larvae and crayfish.

Macrophytes -- Aquatic plants that are large enough to be seen with the naked eye.

Main Stem -- The principal channel of a drainage system into which other smaller streams or rivers flow.

Mass movement -- The downslope movement of earth caused by gravity. Includes but is not limited to landslides, rock falls, debris avalanches, and creep. It does not however, include surface erosion by running water. It may be caused by natural erosional processes, or by natural disturbances (e.g., earthquakes or fire events) or human disturbances (e.g., mining or road construction).

Mean annual discharge -- Daily mean discharge averaged over a period of years. Mean annual discharge generally fills a channel to about one-third of its bank-full depth.

Mean velocity -- The average cross-sectional velocity of water in a stream channel. Surface values typically are much higher than bottom velocities. May be approximated in the field by multiplying the surface velocity, as determined with a float, times 0.8.

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 amplitude -- The distance between points of maximum curvature of successive meanders of opposite phase in a direction normal to the general course of the meander belt, measured between center lines of channels.

Meander belt width -- the distance between lines drawn tangential to the extreme limits of fully developed meanders. Not to be confused with meander amplitude.

Meander length -- The lineal distance down valley between two corresponding points of successive meanders of the same phase.

Mid-channel Bars – bars 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.

Milligrams per liter (mg/l) -- The weight in milligrams of any substance dissolved in 1 liter of liquid; nearly the same as parts per million by weight.

Moraine – a mass of till either carried by an active glacier or deposited on the land after a glacier recedes.

Natural flow -- The flow past a specified point on a natural stream that is unaffected by stream diversion, storage, import, export, return flow, or change in use caused by modifications in land use.

Neck cutoff -- A channel migration feature where the land that separates a meander bend is cut off by the lateral migration of the channel. This process may be part of the equilibrium regime or associated with channel instability.

Outfall -- The mouth or outlet of a river, stream, lake, drain or sewer.

Outwash – water-transported material carried away from the ablation zone of a melting glacier.

Oxbow -- An abandoned meander in a river or stream, caused by cutoff. Used to describe the U-shaped bend in the river or the land within such a bend of a river.

Peat -- Partially decomposed plants and other organic material that build up in poorly drained wetland habitats.

Perched groundwater -- Groundwater supported by a zone of material of low permeability located above an underlying main body of groundwater with which it is not hydrostatically connected.

Perennial streams -- Streams that flow continuously.

Permeability -- The capability of soil or other geologic formations to transmit water.

pH -- The negative logarithm of the molar concentration of the hydrogen ion, or, more simply acidity.

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. A channel straightened for agricultural purposes has a highly impacted planform.

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

Pond -- A body of water smaller than a lake, often artificially formed.

Pool -- A reach of stream that is characterized by deep, low-velocity water and a smooth surface.

Potential plant height -- the height to which a plant, shrub or tree would grow if undisturbed.

Probability of exceedance -- The probability that a random flood will exceed a specified magnitude in a given period of time.

Railroads – Used or unused railroad infrastructure.

Rapids -- A reach of stream that is characterized by small falls and turbulent, high-velocity water.

Reach -- A section of stream having relatively uniform physical attributes, such as valley confinement, valley slope, sinuosity, dominant bed material, and bed form, as determined in the Phase 1 assessment.

Rearing habitat -- Areas in rivers or streams where juvenile fish find food and shelter to live and grow.

Reference stream type --Uses preliminary observations to determine the natural channel form and process that would be present in the absence of anthropogenic impacts to the channel and the surrounding watershed.

Refuge area -- An area within a stream that provides protection to aquatic species during very low and/or high flows.

Regime theory -- A theory of channel formation that applies to streams that make a part of their boundaries from their transported sediment load and a portion of their transported sediment load from their boundaries. Channels are considered in regime or equilibrium when bank erosion and bank formation are equal.

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

Riffle -- A reach of stream that is characterized by shallow, fast-moving water broken by the presence of rocks and boulders.

Riffle-pool ratio -- The ratio of surface area or length of pools to the surface area or length of riffles in a given stream reach; frequently expressed as the relative percentage of each category. Used to describe fish habitat rearing quality.

Riffle-step ratio-- ratio of the distance between riffles to the stream width.

Riparian area -- An area of land and vegetation adjacent to a stream that has a direct effect on the stream. This includes woodlands, vegetation, and floodplains. Riparian buffer is the width of naturally vegetated land adjacent to the stream between the top of the bank (or top of slope, depending on site characteristics) 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. The buffer serves to protect the water body from the impacts of adjacent land uses. Riparian corridor includes lands defined by the lateral extent of a stream's meanders necessary to maintain a stable stream dimension, pattern, profile, and sediment regime. For instance, in stable pool-riffle streams, riparian corridors may be as wide as 10-12 times the channel's bankfull width. In addition the riparian corridor typically corresponds to the land area surrounding and including the stream that supports (or could support if unimpacted) a distinct ecosystem, generally with abundant and diverse plant and animal communities (as compared with upland communities).

Riparian habitat -- The aquatic and terrestrial habitat adjacent to streams, lakes, estuaries, or other waterways.

Riparian -- Located on the banks of a stream or other body of water.

Riparian vegetation -- The plants that grow adjacent to a wetland area such as a river, stream, reservoir, pond, spring, marsh, bog, meadow, etc., and that rely upon the hydrology of the associated water body.

Ripple -- (1) A specific undulated bed form found in sand bed streams. (2) Undulations or waves on the surface of flowing water.

Riprap -- Rock or other material with a specific mixture of sizes referred to as a "gradation," used to stabilize streambanks or riverbanks from erosion or to create habitat features in a stream.

River channels --Large natural or artificial open streams that continuously or periodically contain moving water, or which form a connection between two bodies of water.

River miles --Generally, miles from the mouth of a river to a specific destination or, for upstream tributaries, from the confluence with the main river to a specific destination.

River reach -- Any defined length of a river.

River stage -- The elevation of the water surface at a specified station above some arbitrary zero datum (level).

Riverine -- Relating to, formed by, or resembling a river including tributaries, streams, brooks, etc.

Riverine habitat -- The aquatic habitat within streams and rivers.

Roads -- Transportation infrastructure. Includes private, town, state roads, and roads that are dirt, gravel, or paved.

Rock -- A naturally formed mass of minerals.

Rootwad -- The mass of roots associated with a tree adjacent to or in a stream that provides refuge for fish and other aquatic life.

Run (in stream or river) -- A reach of stream characterized by fast-flowing, low-turbulence water.

Runoff -- Water that flows over the ground and reaches a stream as a result of rainfall or snowmelt.

Sand -- Small substrate particles, generally from 0.002 to 0.08 in diameter. Sand is larger than silt and smaller than gravel.

Scour -- The erosive action of running water in streams, which excavates and carries away material from the bed and banks. Scour may occur in both earth and solid rock material and can be classed as general, contraction, or local scour.

Sediment -- Soil or mineral material transported by water or wind and deposited in streams or other bodies of water.

Sedimentation -- (1) The combined processes of soil erosion, entrainment, transport, deposition, and consolidation. (2) Deposition of sediment.

Seepage -- The gradual movement of a fluid into, through, or from a porous medium. Segment: A relatively homogenous section of stream contained within a reach that has the same reference stream characteristics but is distinct from other segments in the reach in one or more of the following parameters: degree of floodplain encroachment, presence/absence of grade controls, bankfull channel dimensions (W/D ratio, entrenchment), channel sinuosity and slope, riparian buffer and corridor conditions, abundance of springs/seeps/adjacent wetlands/stormwater inputs, and degree of channel alterations.

Sensitivity -- of the valley, floodplain, and/or channel condition to change due to natural causes and/or anticipated human activity.

Shoals -- unvegetated deposits of gravels and cobbles adjacent to the banks that have a height less than the average water level. In channels that are over-widened, the stream does not have the power to transport these larger sediments, and thus they are deposited throughout the channel as shoals.

Silt -- Substrate particles smaller than sand and larger than clay; between 0.0001 and 0.002 inches in diameter.

Siltation -- The deposition or accumulation of fine soil particles.

Sinuosity -- The ratio of channel length to direct down-valley distance. Also may be expressed as the ratio of down-valley slope to channel slope.

Slope -- The ratio of the change in elevation over distance.

Slope stability -- The resistance of a natural or artificial slope or other inclined surface to failure by mass movement.

Snag -- Any standing dead, partially dead, or defective (cull) tree at least 10 in. in diameter at breast height and at least 6 ft tall. Snags are important riparian habitat features.

Spawning -- The depositing and fertilizing of eggs (or roe) by fish and other aquatic life.

Spillway -- A channel for reservoir overflow.

Stable channel -- A stream channel with the right balance of slope, planform, and cross section to transport both the water and sediment load without net long-term bed or bank sediment deposition or erosion throughout the stream segment.

Stone -- Rock or rock fragments used for construction.

Straightening -- the removal of meander bends, often done in towns and along roadways, railroads, and agricultural fields.

Stream -- A general term for a body of water flowing by gravity; natural watercourse containing water at least part of the year. In hydrology, the term is generally applied to the water flowing in a natural narrow channel as distinct from a canal. Stream banks are features that define the channel sides and contain stream flow within the channel; this is the portion of the channel bank that is between the toe of the bank slope and the bankfull elevation. The banks are distinct from the streambed, which is normally wetted and provides a substrate that supports aquatic organisms. The top of bank is the point where an abrupt change in slope is evident, and where the stream is generally able to overflow the banks and enter the adjacent floodplain during flows at or exceeding the average annual high water.

Stream channel -- A long narrow depression shaped by the concentrated flow of a stream and covered continuously or periodically by water.

Stream condition -- Given the land use, channel and floodplain modifications documented at the assessment sites, the current degree of change in the channel and floodplain from the reference condition for parameters such as dimension, pattern, profile, sediment regime, and vegetation.

Stream gradient -- A general slope or rate of change in vertical elevation per unit of horizontal distance of the bed, water surface, or energy grade of a stream.

Stream morphology -- The form and structure of streams.

Stream order -- A hydrologic system of stream classification. Each small unbranched tributary is a first-order stream. Two first-order streams join to make a second-order stream. A third-order stream has only first-and second-order tributaries, and so forth.

Stream reach -- An individual segment of stream that has beginning and ending points defined by identifiable features such as where a tributary confluence changes the channel character or order.

Stream type -- Gives the overall physical characteristics of the channel and helps predict the reference or stable condition of the reach.

Stream type departure -- When the current stream type differs from the reference stream type as a response to anthropogenic or severe natural disturbances. These departures are often characterized by large-scale incision, deposition, or changes in planform.

Streambank armoring – The installation of concrete walls, gabions, stone riprap, and other large erosion resistant material along stream banks.

Streambank erosion -- The removal of soil from streambanks by flowing water.

Streambank stabilization -- The lining of streambanks with riprap, matting, etc., or other measures intended to control erosion.

Streambed -- (1) The unvegetated portion of a channel boundary below the baseflow level. (2) The channel through which a natural stream of water runs or used to run, as a dry streambed.

Streamflow -- The rate at which water passes a given point in a stream or river, usually expressed in cubic feet per second (cfs).

Step (in a river system) --A step is a steep, step-like feature in a high gradient stream (> 2%). Steps are composed of large boulders lines across the stream. Steps are important for providing grade-control, and for dissipating energy. As fast-shallow water flows over the steps it takes various flow paths thus dissipating energy during high flow events.

Substrate -- (1) The composition of a streambed, including either mineral or organic materials. (2) Material that forms an attachment medium for organisms.

Surface erosion -- The detachment and transport of soil particles by wind, water, or gravity. Or a group of processes whereby soil materials are removed by running water, waves and currents, moving ice, or wind.

Surface water -- All waters whose surface is naturally exposed to the atmosphere, for example, rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc., and all springs, wells, or other collectors directly influenced by surface water.

Suspended sediment -- Sediment suspended in a fluid by the upward components of turbulent currents, moving ice, or wind.

Suspended sediment load -- That portion of a stream's total sediment load that is transported within the body of water and has very little contact with the streambed.

Tailwater -- (1) The area immediately downstream of a spillway. (2) Applied irrigation water that runs off the end of a field.

Thalweg -- (1) The lowest thread along the axial part of a valley or stream channel. (2) A subsurface, groundwater stream percolating beneath and in the general direction of a surface stream course or valley. (3) The middle, chief, or deepest part of a navigable channel or waterway.

Tractive Force --The drag on a streambed or bank caused by passing water, which tends to pull soil particles along with the streamflow.

Transpiration -- An essential physiological process in which plant tissues give off water vapor to the atmosphere.

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

Turbidity -- A measure of the content of suspended matter that interferes with the passage of light through the water or in which visual depth is restricted. Suspended sediments are only one component of turbidity.

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

Valley confinement -- Referring to the ratio of valley width to channel width. Unconfined channels (confinement of 4 or greater) flow through broader valleys and typically have higher sinuosity and area for floodplain. Confined channels (confinement of less than 4) typically flow through narrower valleys.

Valley wall -- The side slope of a valley, which begins where the topography transitions from the gentle-sloped valley floor. The distance between valley walls is used to calculate the valley confinement.

Variable-stage stream -- Stream flows perennially but water level rises and falls significantly with storm and runoff events.

Velocity -- In this concept, the speed of water flowing in a watercourse, such as a river.

Washout -- (1) Erosion of a relatively soft surface, such as a roadbed, by a sudden gush of water, as from a downpour or floods. (2) A channel produced by such erosion.

Water quality -- A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Waterfall -- A sudden, nearly vertical drop in a stream, as it flows over rock.

Watershed -- An area of land whose total surface drainage flows to a single point in a stream.

Watershed management -- The analysis, protection, development, operation, or maintenance of the land, vegetation, and water resources of a drainage basin for the conservation of all its resources for the benefit of its residents.

Watershed project -- A comprehensive program of structural and nonstructural measures to preserve or restore a watershed to good hydrologic condition. These measures may include detention reservoirs, dikes, channels, contour trenches, terraces, furrows, gully plugs, revegetation, and possibly other practices to reduce flood peaks and sediment production.

Watershed restoration -- Improving current conditions of watersheds to restore degraded habitat and provide long-term protection to aquatic and riparian resources.

Weir -- A structure to control water levels in a stream. Depending upon the configuration, weirs can provide a specific "rating" for discharge as a function of the upstream water level.

Wetland -- Areas adjacent to, or within the stream, with sufficient surface/groundwater influence to have present hydric soils and aquatic vegetation (e.g. cattails, sedges, rushes, willows or alders).

Width/depth ratio -- The ratio of channel bankfull width to the average bankfull depth. An indicator of channel widening or aggradation, and used for stream type classification.