Ompompanoosuc Watershed
Phase 1 Geomorphic Assessment

Orange and Windsor Counties, Vermont

April 16, 2009

Main Stem of Ompompanoosuc River in Thetford, Vermont

Prepared by: Bear Creek Environmental, LLC

Prepared for: Thetford Conservation Commission

Acknowledgments

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We would especially like to thank Li Shen, of the Thetford Conservation Commission, who volunteered numerous hours conducting the windshield survey, contributed important information regarding local information within the watershed, and provided overall coordination of the project. Funding for the project was provided by a grant from the Vermont Clean and Clear Program sponsored by the Vermont Agency of Natural Resources.

Main stem of Ompompanoosuc River north of the West Branch confluence in Thetford, VT

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Phase 1 Stream Geomorphic Assessment

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1.0 EXECUTIVE SUMMARY

A Phase I Stream Geomorphic Assessment of the Ompompanoosuc Watershed was conducted by Bear Creek Environmental, LLC under the direction of the Thetford Conservation Commission (TCC). The project was funded through a Vermont Clean and Clear Grant sponsored by the Vermont Agency of Natural Resources. A Phase 1 assessment provides information about the physical condition within a watershed and the factors that influence the stability of the river systems by using a combination of remote sensing (i.e. mapping) and windshield surveys. During a windshield survey, quick observations of the stream channel and river corridor are made from public access points. The mapping information and windshield survey observations are used to examine the natural and human disturbances that may have influenced the river. The protocols developed by the Vermont River Management Program were employed to complete the Phase I assessment. The focus of the Phase 1 study is to evaluate impacts that may cause channel adjustment such as floodplain modifications, channel modifications, and land use. A glossary of terms is provided at the end of this report to aid the reader with technical terms.

Of the 16 parameters measured during the Phase 1 Assessment, corridor land use and the lack of riparian buffers were the categories identified as having the greatest potential for causing channel adjustment in the Ompompanoosuc Watershed. A review of orthophotos and topographic maps show that there is a lack of high quality riparian zone in many locations in this watershed. Other categories including watershed land use, channel straightening, berms and roads, river corridor development, meander belt width and wavelength, and ice/debris jam potential were also identified as causing channel adjustment.

Most of the reaches (sections of river with similar characteristics) on the main stem of the Ompompanoosuc River have stream types that are very susceptible to shifts in both lateral and vertical stability caused by direct channel disturbance, the removal and alteration of streambank vegetation, and changes in the flow and sediment regimes of the contributing watershed. The Phase 1 watershed assessment information presented in this report will be used as the basis for recommending reaches for rapid habitat and geomorphic assessments (Phase 2 assessments) within the Ompompanoosuc Watershed. Due to the high level of observed impact and reach condition, forty seven of the 83 assessed reaches have been recommended for Phase 2 assessments. These reaches are located on the main stem of the Ompompanoosuc River, Avery Brook, Ompompanoosuc West Branch, Barker Brook, Lake Fairlee outlet, Middle Brook, Blood Brook and Tributary three to the Ompompanoosuc River.

2.0 PROJECT OVERVIEW

Bear Creek Environmental (BCE) was retained by the Thetford Conservation Commission (TCC), as part of a grant with the Vermont River Management Program, to complete the Phase 1 Stream Geomorphic Assessment for the Ompompanoosuc Watershed. This Phase 1 assessment provides a stream impact rating that enables a priority ranking for each reach. This ranking can be used to determine where more detailed Phase 2 Geomorphic Assessments should be conducted within the watershed.

3.0 BACKGROUND INFORMATION

3.1 Description of Study Area

The Ompompanoosuc River is one of the major rivers in Vermont that flows into the Connecticut River (Figure 1). The drainage area of the Ompompanoosuc Watershed is 137 square miles. The portion of the watershed that was studied lies within Orange and Windsor Counties and includes the following streams: Ompompanoosuc River main stem, Middle Brook, Blood Brook, Lake Fairlee Outlet, Barker Brook, Avery Brook, Ompompanoosuc West Branch up to Abbott Brook, and Abbott Brook. A Phase 1 Geomorphic Assessment was already conducted on reaches of the West Branch of the Ompompanoosuc River Watershed that are located in the Town of Strafford. For this project, the only areas of the West Branch watershed that were assessed were the two most downstream reaches on the West Branch (located in Thetford) and Abbott Brook. Locations along this river have undergone channel alterations in the past as well as some development within their river corridors.

The Ompompanoosuc River Watershed is dominated by forested land (Figure 2). However, cropland, agricultural fields, or urban land are sub-dominant land uses within the Ompompanoosuc Watershed. Urban, residential and industrial lands are concentrated along the river corridor, especially near the mouth of the Ompompanoosuc River and in the village center of West Fairlee.

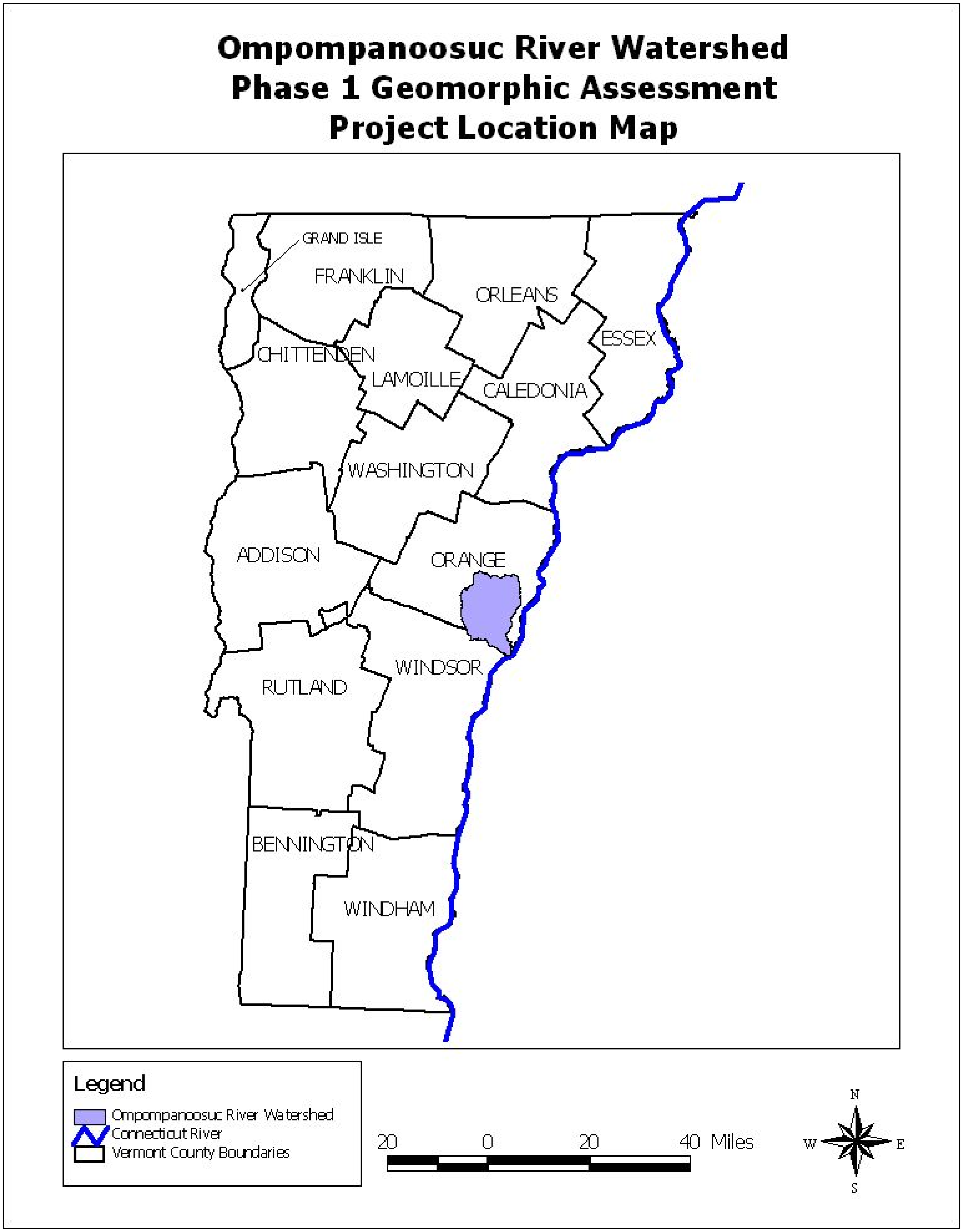

Figure 1. Project Location Map for the Phase 1 Assessment

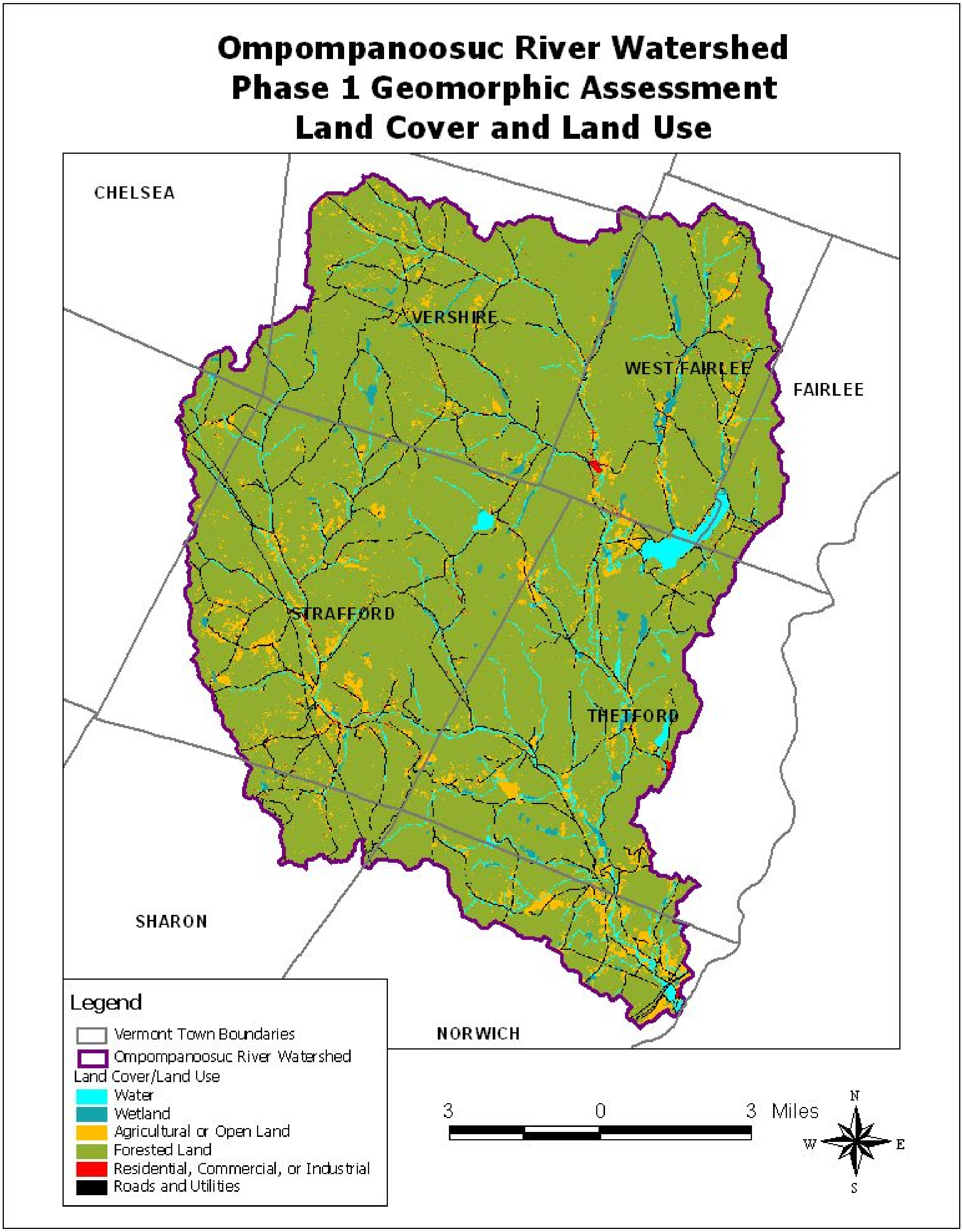

Figure 2. Land Cover and Land Use in Ompompanoosuc River Watershed

The Ompompanoosuc Watershed is located in the Connecticut Valley-Gaspe Basin Province, which contains thick sedimentary calcareous deposits (Doolan, 1996). The bedrock geology of this region is predominantly made up of metamorphosed sedimentary rocks and volcanic intrusions (Van Diver, 1987). This region was later worked by glaciation and now contains significant glacial drift deposits that have been downcut by the flowing rivers and streams (Van Diver, 1987). The dominant surficial sediments (i.e. sediment deposits above bedrock) within the Ompompanoosuc valley are primarily glacial till, ice-contact deposits, and alluvium. Sub-dominant surficial sediments include glacial till, ice-contact deposits, alluvium, glacial lake and other deposits.

The Ompompanoosuc River flows through a gentle gradient valley, except for the most upstream reaches (Table 1). Most reaches on the main stem have a channel slope less than one percent. The greatest slopes are located in the most upstream reaches, but are still all less than five percent on the main stem. Slope percentages for the major tributaries are also shown below in Table 1.

Rivers in the watershed were divided into 98 separate reaches based on similar stream characteristics such as slope and confinement. Of these 98 reaches, 15 were excluded from this study since they were either wetlands or lakes and ponds. Among the excluded lakes and ponds are Norford Lake (on Tributary One to Avery Brook in Norwich and Thetford), Lake Fairlee (on Blood Brook in Thetford, Fairlee and West Fairlee) and Miller Pond (on Tributary Two to Abbott Brook in Strafford). Dams at these lakes and ponds have altered the flow characteristics of the stream. The Union Village Dam in Thetford causes variable flow conditions depending on the time of year. During the winter months (December through April), water is held back and a pool is created in order to prevent the dam gates from freezing. In the warmer months (May through November), water is not held back and the flow exits the outlet conduit of the dam (personal conversation Brian Fitzgerald, 1/21/2009). Other on-stream ponds and impoundments are located on the mainstem, Avery Brook, Barker Brook, and Middle Brook. Tributary One to Avery Brook and Middle Brook provide wetland habitat.

Table 1. Channel Slopes

Watershed	Greatest Reach Slope	Range of other Reach Slopes
Ompompanoosuc River	4.5 %	<1 – 3.7 %
Avery Brook	8 %	2.2 - 5.1 %
Tributary One to Avery Brook	6.5 %	1.6 – 5.6 %
West Branch Ompompanoosuc*	1.7 %	1.0 %
Abbott Brook	5.8 %	2.0 – 2.7 %
Tributary One to Abbott Brook	5.2 %	NA
Tributary Two to Abbott Brook	2.1 %	NA
Barker Brook	6.4 %	2.5 – 6.0 %
Lake Fairlee Outlet	0.31 %	0.30 %
Middle Brook	15 %	< 1 – 5.9 %
Blood Brook	17 %	<1 – 7.0 %
Tributary Three to Ompompanoosuc	9.8 %	1.5 – 4.2 %

Slopes reported for main stem downstream of Abbott Brook
NA – not applicable (only one reach located on tributary)

3.2 Flood History

Between 1995 and 1998 Vermonters suffered nearly $60,000,000 in flood damages (Vermont Agency of Natural Resources, 2006); much of these losses may have been avoided with more stringent floodplain development regulations that address both fluvial erosion hazards and inundation hazards. In order to better understand the flood history of the Ompompanoosuc Watershed, long term peak discharge data from the U.S. Department of the Interior, U.S. Geological Survey (USGS) gauge on the Ayers Brook at Randolph, VT was obtained. The gauge on the main stem of the Ompompanoosuc was not used because the river's flow is regulated at this gauge and would, therefore, not be representative of natural flow conditions. The Ayers Brook gauge provides a continuous record of flow from 1940 through 2007. The drainage area at the Ayers Brook gauge is 31 square miles. Although the drainage area of the Ompompanoosuc is much larger at 137 square miles, it does represent a good regional long term record. The long term record shows peak discharges between a ten year and 25 year recurrence interval occurred during water years[1]

[1] A water year is the twelve month period from October 1 through September 30.

1949 and 2007 as shown below in Figure 3. The annual peak discharge was between the 25 and 50 year recurrence interval in 1952 and exceeded the 50 year recurrence interval in 1973 and 1998. These USGS peak discharge flow values for each year do not account for the effects of flow regulations and diversions.

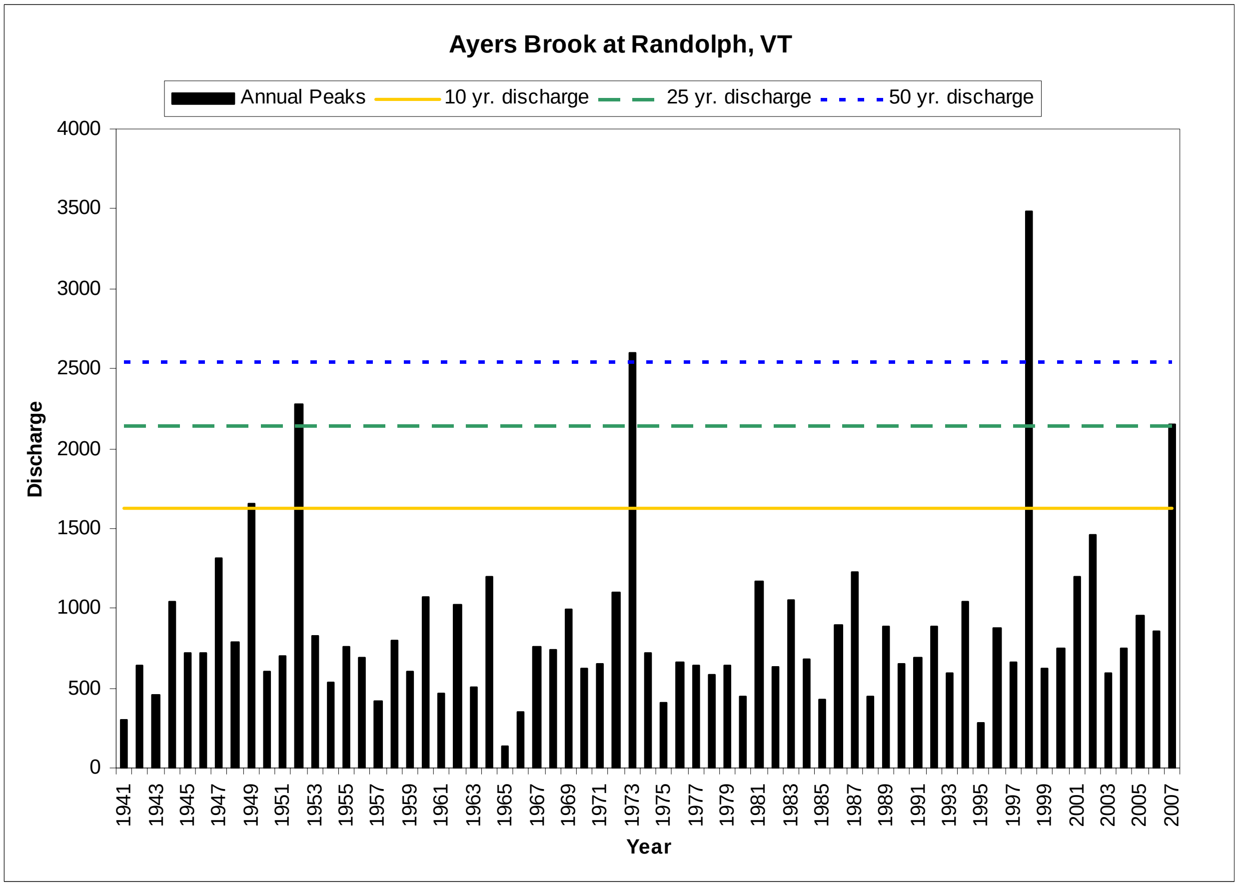

Figure 3: Flood frequency analysis for Ayers Brook

According to Thetford Conservation Commission member Li Shen, there was a flash flood on August 5, 2003 on an unnamed tributary to the West Branch of the Ompompanoosuc that runs along Poor Farm Road in Thetford. This flash flood was the result of localized heavy rains and it caused the brook to cut a trench 8-10 feet deep across Tucker Hill Road. Culverts as well as parts of the road were washed away (Hookway, 2003). Residents in the area reported that a small stream normally 1.5 feet wide became as wide as 30 feet very quickly (Hookway, 2003). A washout on Sawnee Bean Road along Barker Brook in Thetford also occurred that day.

4.0 PHASE 1 METHODOLOGY

The Phase I assessment was conducted by BCE following procedures specified in the Vermont Stream Geomorphic Assessment Handbook Phase 1 (Vermont Agency of Natural Resources 2007). BCE used version 4.59 of the Stream Geomorphic Assessment Tool (SGAT) GIS extension. Assessment data were recorded on the DEC Phase I data sheets or obtained digitally, and when possible, entered or uploaded into the Vermont River Management Program's Data Management System (DMS).

4.1 Phase 1 Parameters

During the Phase 1 Assessment, data were collected for each parameter in Table 2. In order to explain the level of impact on each reach and to determine priority rankings, impact ratings were developed. The ratings were based on scores which were assigned to channel, floodplain, and land use modifications within each reach. Each parameter in Table 2 was rated according to the following menu options (NS – not significant, low impact, high impact or No data). A zero was scored for options NS and No data, a one for low impact and a two for high impact.

Table 2. Parameters Included in Impact Scores

Step #	Parameter
4.1	Watershed Land Cover/ Land Use
4.2	Corridor Land Cover/ Land Use
4.3	Riparian Buffer Width
5.1	Flow Regulations and Water Withdrawals
5.2	Bridges and Culverts
5.3	Bank Armoring and Revetments
5.4	Channel Modifications
5.5	Dredging and Gravel Mining History
6.1	Berms and Roads
6.2	River Corridor Development
6.3	Depositional Features
6.4	Meander Migration / Channel Avulsion
6.5	Meander Width Ratio

Table 2. Parameters Included in Impact Scores	
Step #	**Parameter**
6.6	Wavelength Ratio
7.1	Bank Erosion – Relative Magnitude
7.2	Ice and Debris Jam Potential

The feature indexing tool (FIT) was used to map features within the channel and river corridor for the following Phase 1steps:

- Step 3.1 Alluvial Fan
- Step 3.2 Grade Control
- Step 4.3 Riparian Buffer Width <25 feet
- Step 5.1 Flow Regulation and Water Withdrawals
- Step 5.2 Bridges and Culverts
- Step 5.3 Bank Armoring and Revetment
- Step 5.4 Channel Straightening
- Step 5.5 Dredging and Gravel Mining
- Step 6.1 Berms and Roads (Encroachments)
- Step 6.2 River Corridor Development
- Step 6.4 Meander Migration / Channel Avulsions
- Step 7.1 Erosion

This tool is an extension of ArcView (a computer mapping program) and utilizes the Vermont Hydrography Dataset (VHD) to automate measuring the length of impact on stream segments and the placement of impact points along the stream. The FIT generated an attribute table, which was uploaded to the DMS. A GIS shapefile was created for points of photos taken during the windshield survey, and shapefiles for depositional features and meander belt width and wavelength ratio locations were also created.

4.2 Phase 1 QA Review

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

5.0 PHASE I RESULTS

5.1 Reach Locations

The Ompompanoosuc Watershed was divided into 98 reaches for the Phase I Assessment (Figure 4). A reach is considered a section of stream with similar characteristics. In general, reach designations were based on similar confinement (valley width), slope, and/or tributary influence. Fifteen reaches were excluded in this study due to wetlands or impoundments, leaving 83 reaches to be assessed. Pages 1 through 4 of the Appendix provide the reach locations including reach description and town where the reach is located.

5.2 Reference Stream Types

Reference stream types are defined as stream channel forms and processes that would exist in the absence of human-related changes to the channel, floodplain, and/or watershed. Stream and valley characteristics, including confinement (natural valley width) and slope, determined through remote sensing, were used to determine the reference stream type. The reference reach characteristics were later refined during the windshield survey. Reference reach typing was based on both the Rosgen (1996) and the Montgomery and Buffington (1997) classification systems.

Table 3 shows the typical characteristics used to determine reference stream types (Vermont Agency of Natural Resources, 2007). Pages 5 through 7 of the Appendix provide a listing of reference stream types for each reach within the project area. Figure 5 shows the various stream types of the reaches within the Ompompanoosuc River Watershed. Most of the reaches on the main stem of the Ompompanoosuc River fall within the "C" stream type. In general, the reference "C" streams are unconfined and have moderate to gentle slopes. The two most downstream reaches on the Ompompanoosuc River and one other reach on the main stem are of stream type "E". "E" channels have a very low width to depth ratio and flow through unconfined valleys with moderate to gentle slopes. These streams are often highly sinuous and have cohesive bank material associated with lacustrine (lake) soils. Eight reaches on the main stem are of stream type B. "B" channels typically flow through confined, semi-confined or narrow valleys and have moderate to steep slopes.

One reach in the upstream section of the main stem of the Ompompanoosuc River has an "A" stream type. "A" streams flow through steep gradient terrain and are often associated with a cascade bed form.

Table 3: Reference Stream Type

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

5.3 Basin Geology and Soils

The characteristics of the Ompompanoosuc Watershed were determined using a combination of soils data, review of topographic maps, and information acquired during the windshield survey. Pages 8 through 11 of the Appendix provide a summary of the basin characteristics, such as alluvial fans, grade control structures, geologic materials, and valley side slopes.

Alluvial fans are wedged shaped sediment deposits carried by a river or stream that is deposited where there is a sharp decrease in slope. In the Ompompanoosuc River Watershed, 11 possible alluvial fans were noted due to abrupt changes in slope.
A grade control is something that prevents the stream from downcutting into its bed. Grade controls such as bedrock ledges and dams were noted in 22 reaches during the windshield survey and from USGS topographic maps or orthophotos. These elements act

as grade controls by keeping the base elevation of a river from being lowered, and thereby prevent the river from incising (i.e. downcutting) in that location. There are four dams on the main stem of the Ompompanoosuc River, two dams on Tributary one to Avery Brook, one dam at the Lake Fairlee outlet, two dams on Middle Brook, one dam on Blood Brook, one dam on Tributary three to the Ompompanoosuc River, and one dam on Tributary two to Abbott Brook. Other grade controls found in the Ompompanoosuc River Watershed include nine ledge grade controls and two waterfalls. The waterfalls were located on Tributary one to Avery Brook and on the main stem of the Ompompanoosuc. Ledge grade controls were found on Avery Brook, the main stem of the Ompompanoosuc, the West Branch of the Ompompanoosuc, and Tributary three to the Ompompanoosuc.

The dominant surficial geology (sediment deposits overlying bedrock) of the Ompompanoosuc River Watershed consists of alluvial, ice-contact deposits, till, and other deposits. The subdominant surficial geology of the watershed consists of alluvial, ice-contact deposits, till, glacial lake and other deposits.

The steepness of the valley side slopes was determined using a combination of topographic maps and the soils layer. Except for the two reaches downstream of Lake Fairlee, the valley side slope steepness in the Ompompanoosuc River Watershed ranged from hilly to extremely steep. The two reaches downstream of the Lake Fairlee outlet had flat valley side slopes.

Pages 12 through 14 of the Appendix provide a summary of the soil characteristics. Most reaches on the main stem of the Ompompanoosuc River contain soils in hydrologic soil group B. Soils in group B are silt loam or loam with a moderate infiltration rate when thoroughly wetted. Sixteen out of the 83 assessed reaches have soils that are flooded frequently. These reaches were located on Barker Brook, the main stem of the Ompompanoosuc, Middle Brook, Blood Brook, and Tributary three to the Ompompanoosuc. Two reaches on the Ompompanoosuc (R03 and R11) have soils that flooded occasionally, and the remaining reaches have soils that either flooded rarely or never. The soils in many reaches are of very severe erodibility.

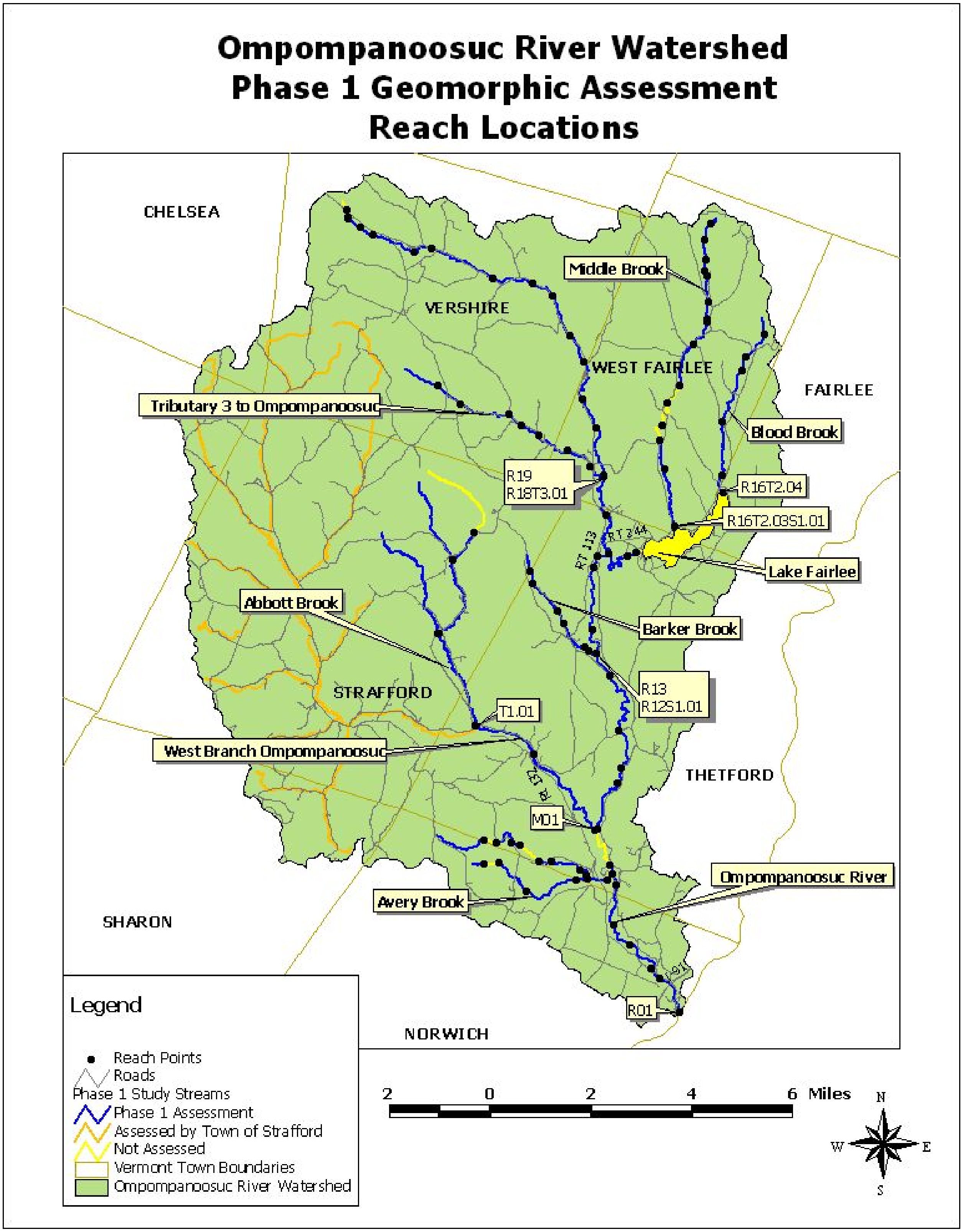

Figure 4. Ompompanoosuc River Watershed Reach Location Map for Stream Geomorphic Assessment

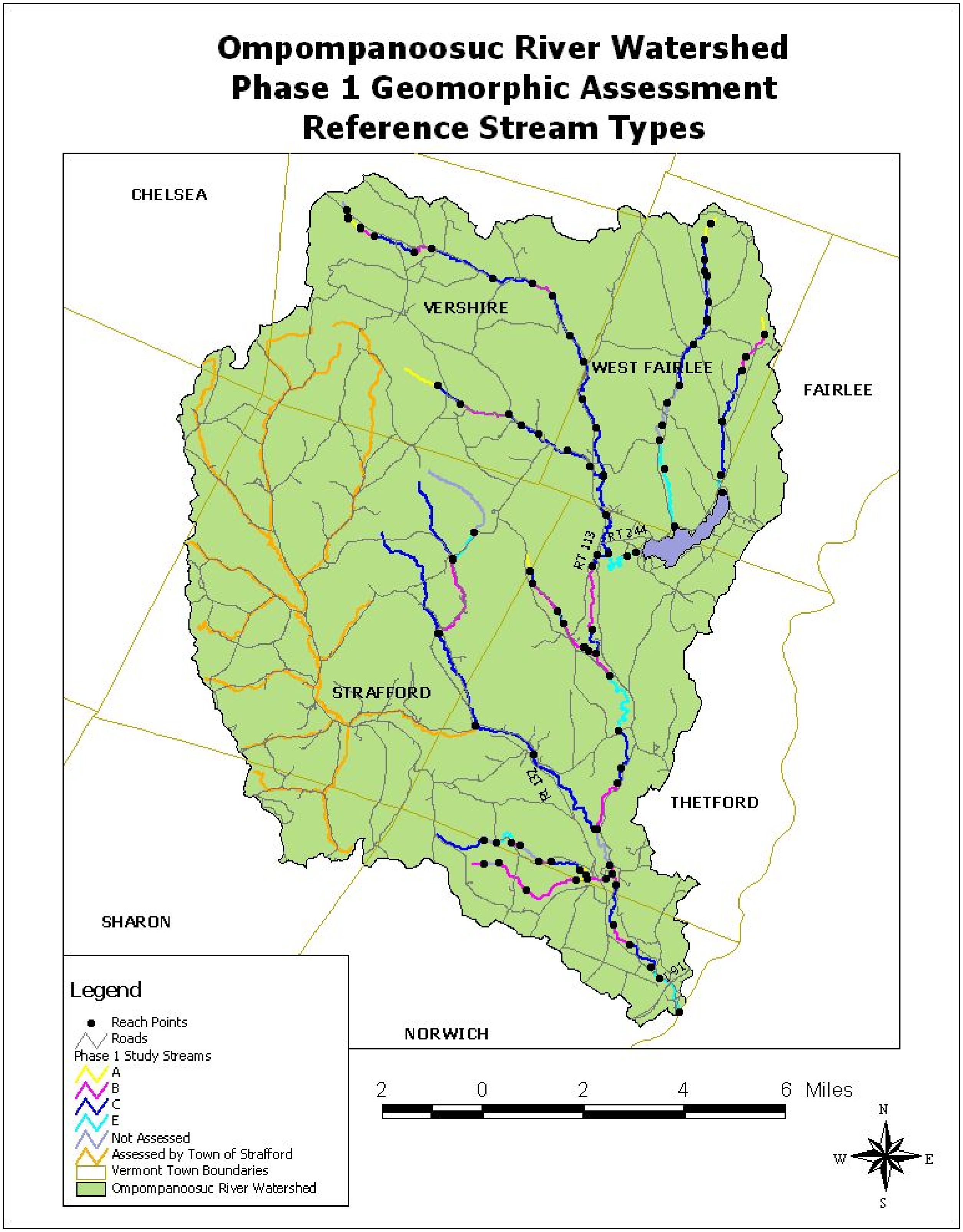

Figure 5. Reference Stream Types within the Ompompanoosuc River Watershed

5.4 Land Cover – Reach Hydrology

The land use within a watershed plays an important role in the hydrology of the receiving waters. The extent of urban and cropland development within the watershed can affect the watershed's response to precipitation. Urban and cropland development often increases peak discharges and runoff due to reduced infiltration and travel time (United States Department of Agriculture 1986). The land use/land cover within the stream corridor itself is also an important parameter to evaluate. This land use/land cover plays an important role in the sediment deposition and erosion which occurs during annual flood events.

As outlined in the Phase I handbook, impact ratings were assigned for watershed land cover/land use and stream corridor land cover/land use as follows:
High – 10% or more is crop and/or urban
Low – Between 2 and 10 % is crop and/or urban
NS – Not Significant – Less than 2 % is crop and/or urban

The land cover/land use information is provided on pages 15 and 16 of the Appendix. With one exception, all of the 83 assessed reaches resulted in a watershed/land use impact rating of low. Reach R16T2.09 (the most upstream reach on Blood Brook) had an impact rating of not significant. The dominant land cover/land use within the watershed was forest for all of the reaches and the subdominant land cover/land use was either urban, field or cropland.

Forty seven reaches in the Ompompanoosuc River Watershed received a high impact rating for corridor land cover/use (because of agriculture or development in the corridor). The dominant corridor land cover/land use for the main stem is primarily forest, with two exceptions where the dominant land cover/land use is urban land. In most reaches, the subdominant land cover/land use in the corridor is urban land, field, or crop land, but there are some reaches where the subdominant land use is forest or shrub land.

5.5 Historic Channel Modifications

Channel modifications may impact a stream reach by affecting the hydraulics and the sediment regime. Historic channel modifications were assessed for all study reaches. These reaches were assessed by evaluating flow regulations, bridge and culvert impacts, bank armoring, windrowing, straightening, and dredging. The percentage by length of reach impacted by one or more of these channel modifications was estimated and is summarized on pages 17 through 19 of the Appendix.

Flow Regulations

Impoundments potentially disrupt natural sediment transport within the reach and are flagged as possible causes of instability. Due to a large storage and release flood control dam on main stem of the Ompompanoosuc, reach R06 was assigned an impact rating of high for flow regulation. A large run of river dam located at the Lake Fairlee outlet also triggered a rating of high for flow regulation on R16T2.02. The rest of the flow regulations are from small run of river impoundments and were assigned an impact rating of low. These flow regulations are located on the tributary to Avery Brook (R06S1.02S1.07), Middle Brook (R16T2.03S1.02 and R16T2.03S1.10), the main stem of the Ompompanoosuc River (R19), and Tributary two to Abbott Brook (T1.S2.01). All other reaches within the watershed have no known flow regulation.

Bridges and Culverts

As part of the Phase I Stream Geomorphic Assessment, bridges and culverts within each reach were identified where roads or driveways crossed the stream on the topographic maps and orthophotos. These stream crossings were confirmed during the windshield survey. The percentage of the reach impacted by stream crossing structures was estimated for the study reaches. Impact ratings for bridge and culverts were evaluated by determining the percentage of the reach length that is channelized, has split flow, or makes a sharp "S" bend upstream or downstream of bridges or culverts. If there are significant channelization, deposition, and sharp bends caused by a bridge or culvert placement, potential hazards during a flood event may occur as well as significant planform change (change in the meander movement and pattern of the stream).

In the Ompompanoosuc River Watershed, the impact from bridge and culverts on stream dimension, pattern or profile was assigned as high for 6 of the 83 reaches (greater than 20% of the reach is impacted by bridges and culverts). These reaches include R01, R02, and R22 (main stem of the Ompompanoosuc River), R12S1.07 (Barker Brook), R15, R18T3.02 (Tributary three to the Ompompanoosuc). The bridges on R01 and R02 are primarily due to Interstate 91, a railroad bridge and Route 132. The bridge at reach R15 is located at the Route 113 crossing at Post Mills. R18T3.02 flows along Beanville Rd. northwest of downtown West Fairlee. R22 is located just upstream of Brimstone Corner. Twenty nine reaches received an impact rating of low (less than 20% of the reach is impacted by bridges and culverts). The remaining reaches had an impact rating of not significant.

Bank Armoring

The amount of bank armoring within a watershed is often indicative of the occurrence of channel processes, which result in bank erosion. Bank armoring is not an effective way to manage stream bank erosion because it can redistribute erosion and/or channel adjustment problems upstream or downstream. It prevents the stream from returning to a state of equilibrium by setting back the channel evolution process (Vermont Agency of Natural Resources 2007). Bank armoring, also called revetments, can be made of a variety of material including wooden cribs, gabions, logs, and rock riprap. The most common type of revetment in Vermont is rock riprap. The following criterion was used to provide an impact rating for human placed bank armoring.

H	High – Greater than 30% of the reach length is armored
L	Low – Between 10 and 30% of the reach length is armored
NS	Not Significant – Less than 10% of the reach length is armored
No Data	Bank armoring has not been evaluated for the entire reach and impact at the reach level is unknown

The two types of revetment noted within the study area were rock rip rap and hard bank. Bank armoring was recorded on 40 of the 83 assessed reaches. Seven of the 83 assessed reaches (R02, R06S1.01, R06S1.02, R15, R23, R26 and R27) had a high impact rating for bank armoring. These reaches are located on the main stem of the Ompompanoosuc and Avery Brook. R02 is located near the intersection of Union Village Road and Route 132.

The reaches on Avery Brook are the two most downstream reaches near the crossing of Route 132 in Union Village. R15 is located where Route 113 crosses the river in Post Mills, and Reach R23 is found along Route 113 north of Brimstone Corner. R26 and R27 also follow along Route 113 above the centers of Mill Village and Vershire, respectively. Eighteen reaches had an impact rating of low while the impacts on the remaining reaches were not significant. The reaches having low ratings for bank armoring were located on the main stem of the Ompompanoosuc, Tributary one to Avery Brook, Barker Brook, Middle Brook, and Tributary three to the Ompompanoosuc River.

Channel Modifications (Windrowing and Straightening)

The Ompompanoosuc River Watershed has experienced extensive historic straightening primarily due to the development of roads parallel to the river. Channel straightening was identified by reviewing orthophotos, contacting the state river management engineer, and through field confirmation during the windshield survey.

During the Phase 1 assessment, the total reach length (in feet) and the percentage of the reach length directly impacted by channel modification were noted for 45 of the 83 reaches. Categories considered as part of the Step 5.4 (Channel Modifications) included the following menu options:

- Straightening – Manual straightening of a channel without windrowing.
- With Windrowing – pushing gravel up from the stream bed onto the top of either bank as part of the straightening of the river.
- None – No known channel straightening.
- Not evaluated – All data sources have not been evaluated.

Portions of stream reaches that have been historically channelized or straightened are shown below in Figure 6. Thirty six of the 83 reaches were given an impact rating of high (greater than 20% of reach has been impacted) due to channel straightening while nine reaches had an impact rating of low (less than 20% of reach length impacted).

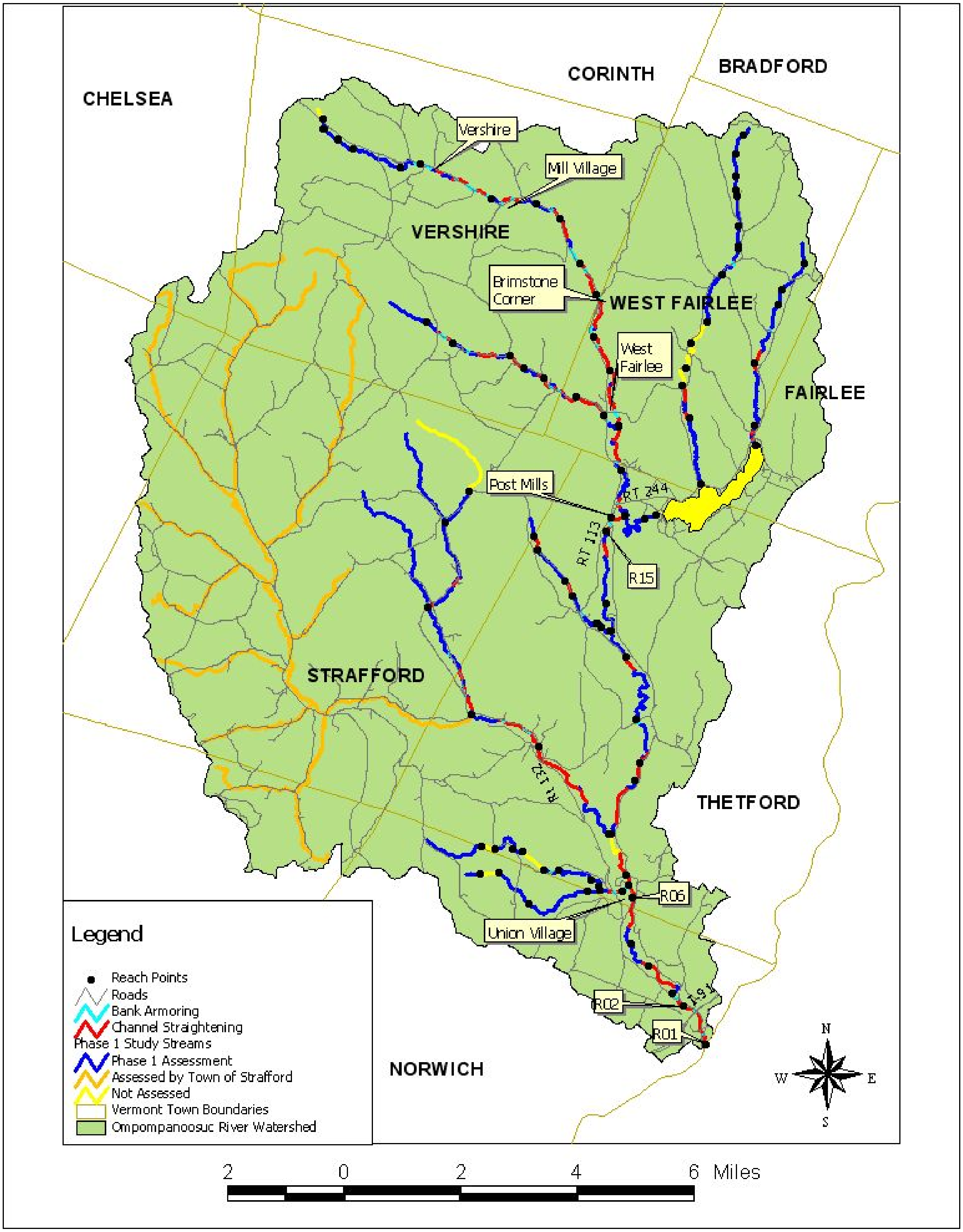

Figure 6. In-stream Channel Modifications Identified for the Ompompanoosuc River Watershed

Dredging History

BCE contacted DEC Stream Alteration Engineers Patrick Ross and Barry Cahoon and asked if they had any record of dredging within the Ompompanoosuc River Watershed. Mr. Cahoon could not recall any dredging in the watershed. Mr. Ross also did not have any record of dredging in the Ompompanoosuc Watershed. During the windshield survey, BCE did not observe any areas where there may have been dredging and/or gravel extraction.

5.6 Floodplain Modifications

In the Floodplain Modifications step of the Phase I assessment, careful attention is paid to infrastructure and other development which restricts the river's access to the floodplain, resulting in vertical or lateral confinement of flood flows. The parameters included in this step are: Berms and Roads, River Corridor Development, Depositional Features, Meander Migration/Channel Avulsion, Meander Width Ratio, and Wavelength Ratio. The Berms and Roads and River Corridor Development parameters explain the degree to which berms (barriers higher than floodplain elevation), roads, and development have encroached upon the river corridor. Depositional features refer to sediment deposits, which are higher than the average water level, located within the stream channel. Meander Migration is when the bends (meanders) in a channel move considerably over time. When a meander continues to move, it can break off from the main channel, which is called an avulsion. The Meander Width Ratio is a way to measure the geometry of a meander. The ratio of the width of a meander (belt width) to the width of the natural channel can help to determine floodplain modifications. Another measure of meander geometry is the Wavelength Ratio. The Wavelength Ratio is simply the ratio of the length between meanders to the natural channel width. Some of the primary factors, which may influence floodplain function of the Ompompanoosuc River Watershed are discussed below. Pages 20 and 21 of the Appendix contain the Phase 1 information for floodplain modifications.

Berms and Roads

An estimate of the percentage of the river corridor length along which berms, roads, railroad, or improved paths run parallel to the stream was estimated for the study reaches using information from maps, orthophotos, and the windshield survey. Reaches where berms, roads, railroads or improved paths were located along 20 percent or more of the river corridor were given impact ratings of high.

Thirty six reaches within the Ompompanoosuc River Watershed received an impact rating of high for berms and roads (>20% berms, roads, railroads or improved paths within the river corridor by length). Many of these reaches are concentrated along the lower Ompompanoosuc main stem adjacent to Route 132, the access road to Union Village Dam, and Route 113. All but one of the reaches on Tributary three to the Ompompanoosuc had a high impact rating. These reaches are located along Beanville Road, South Vershire Road, and Eastman Crossroad in West Fairlee and Vershire. Ten reaches received an impact rating of low for berms and roads (5 to 20% berms, roads, railroads or improved paths within the river corridor by length), and the remaining three reaches with encroaching berms or roads had an impact rating of not significant (less than 5% encroachments by length).

River Corridor Development

The river corridor development parameter looks at whether developments within the river corridor are effectively decreasing the belt width within which the river can adjust. The percentage of the reach length with houses, fill, parking lots or other development within the river corridor was determined using topographic maps, orthophotos, GIS shapefile of emergency 911 structures, and knowledge from the windshield survey.

Nineteen out of the 83 assessed reaches within the Ompompanoosuc River Watershed had an impact rating of high (>20% development within the river corridor by length) for development. In general, the river corridor development is high along the Ompompanoosuc main stem downstream of Union Village Dam and nearby and upstream of West Fairlee Village. Corridor development is also high along Tributary three to the Ompompanoosuc near West Fairlee Village. Twenty two reaches had a low impact rating (5% to 20% of reach impacted) for river corridor development. The remaining 13 reaches with development in their river corridor were rated as not significantly impacted.

Depositional Features

As mentioned earlier, depositional features refer to sediment deposits, which are higher than the average water level, located within the stream channel. They are formed by the deposition of transported sediment in lower velocity areas within the channel. The DEC has included depositional features as a component of the Phase I analysis because these features are indicative of an increased sediment load and a high likelihood that the streambed is actively aggrading and/or undergoing lateral migration. An unvegetated bar indicates the bar has recently formed or is in the process of growing.

The National Agricultural Imagery Program (NAIP) orthophotos as well as results from the windshield survey were used to evaluate depositional features within the Ompompanoosuc River Watershed. The presence of bars (mid-channel, side, or point bars), delta bars, and islands were noted in 37 of the study reaches. One reach in the Ompompanoosuc River Watershed was classified as having a high impact from sediment deposition. This reach was the most downstream reach on the West Branch of the Ompompanoosuc (M01). Twenty one reaches were given a low impact rating due primarily to the presence of point bars, mid-channel bars, delta bars and side bars. The 15 remaining reaches, where depositional features were observed, were not significant for depositional features.

Meander Migration

Migration occurs when a channel has moved due to bank erosion on outside bends. Bifurcation, also known as braiding, is when the stream's flow has split, and an avulsion is when a new channel has been created as a result of a meander cut off. A neck-cutoff is when an avulsion is impending. Orthophotos were used to evaluate areas where the Ompompanoosuc River and its major tributaries have migrated, bifurcated, or avulsed. Current NAIP digital ortho imagery from 2003 and historic orthophotos from the 1970s were compared to evaluate changes in the location of the river channel over time. The current and the historic photos span a range of approximately 25 years. In addition to the aerial photo analysis, windshield surveys helped to verify channel avulsions and islands observed on the orthophotos.

Nine reaches in this watershed received an impact rating of high (frequent occurrences) due to evidence of frequent channel migration, avulsion, and neck cutoffs (Figure 7). These reaches are located on the West Branch of the Ompompanoosuc, the main stem of the Ompompanoosuc, Middle Brook, and Blood Brook. On the main stem Ompompanoosuc, high impact reaches are upstream of the confluence with the West Branch (R08, R11, R17, and R28). Reaches in the lower section of Blood Brook (near the Lake Fairlee inlet) had high impact ratings for channel migration (R16T2.04 and R16T2.05). The most downstream reach on Middle Brook (R16T2.03S1.01) and the reach just upstream of the wetland area (R16T2.03S1.06) also had high impact ratings. This active movement of the stream channel is an indicator of significant channel adjustment. Thirteen reaches that showed few occurrences of channel migration, avulsion, and neck cutoffs were classified as having low impact from channel migration. These reaches are located on the main stem of the Ompompanoosuc, the West Branch of the Ompompanoosuc, Abbott Brook, Middle Brook, and Tributary three to the Ompompanoosuc River. The remaining four reaches, where meander migration was noted, were not significantly impacted. These reaches are located on the main stem of the Ompompanoosuc River, Barker Brook, and the Lake Fairlee outlet.

Figure 7. Channel Avulsion on R18T3.07 (Tributary Three to Ompompanoosuc River)

Meander Width and Wavelength

The meander belt width is the horizontal distance between the two opposite, outside banks on fully developed meanders. The meander width ratio is calculated by dividing the average belt width for the reach by the bankfull width. Leopold 1994 and Williams 1986 (cited in Vermont Agency of Natural Resources, 2007) consider unconfined, gravel dominated streams with moderate to gentle gradients, which are in regime, to have belt widths in the range of 5 to 8 times the channel width. Meander belt width helps to interpret what process may be going on in the stream reach, e.g. degradation, aggradation, widening, or planform adjustment. Degradation occurs when the stream bed is downcutting. Aggradation refers to excess sediment depositing in the stream bed. Widening of the channel results from stream banks eroding and planform adjustment is when the channel has changed its meander pattern. High values of meander belt width are an indication that aggradation may be occurring due to an increase in sediment, while lower values indicate that the stream is degrading due to a straighter and steeper channel (Vermont Agency of Natural Resources, 2007).

The meander wavelength consists of two bend ways. The wavelength ratio is calculated by dividing the average wavelength by the bankfull channel width. Leopold 1994 and Williams 1986 (cited in Vermont Agency of Natural Resources, 2007) have also shown unconfined, gravel dominated streams in shallow-sloped valleys to have wavelengths in the range of 10 to 12 times the channel width. Higher meander wavelength values indicate that the stream has become straighter and steeper and has undergone degradation. Lower meander wavelength values indicate an increase in sediment in the stream channel (aggradation). (Vermont Agency of Natural Resources, 2007).

The NAIP series (1:5000) orthophotos in conjunction with topographic maps were used to determine the meander belt width and the meander wavelength for reference C or E riffle-pool or ripple dune stream types (i.e. unconfined systems). The topographic maps were used to determine the valley direction, while the most current orthophoto series was used to provide the accurate location of channel meanders.

Twenty five of the 43 type "C" or "E" reaches assessed for meander geometry in the Ompompanoosuc River Watershed fell outside of the range expected for channels which are in balance. These reaches were rated as high impact for meander width ratio (<3 or >10). The length of 23 of these reaches had been straightened by more than 50% and were assigned a meander width ratio of 1.0. Eleven reaches were classified with a low impact rating (>3 and <5 or >8 and <10) for meander belt width. Seven reaches were not significantly impacted (>5 and <8).

Twenty eight of the 43 type "C" or "E" reaches assessed for meander geometry received high impact ratings for wavelength ratio (<6 or >16). For 23 of these reaches, the wavelength ratio was 1.0 since they were more than 50% straightened by length. Six reaches were classified as having an impact rating of low (>6 and <8 or >14 and <16). The remaining nine assessed reaches of stream type "C" or "E" were not significantly impacted for wavelength ratio (>8 and <14).

5.7 Bed and Bank Windshield Survey

In order to verify data collected remotely, the Phase 1 assessment includes a field observation component known as a "windshield survey". The windshield survey involves driving around the watershed to rapidly verify data collected in the office and flag any areas of great concern that are easily observed from the banks of the river.

Three major observations were recorded during the windshield survey. These observations include:

1. stream type (including dominant bed form, dominant bed material, and subclass slope),
2. bank erosion/bank height, and
3. debris/ ice jam potential.

The results of the windshield survey are summarized on pages 22 through 24 of the Appendix. The stream type, dominant bed form and dominant bank material were previously discussed under Section 4.2, Reference Stream Types. The amount of bank erosion observed along a reach and the bank height were evaluated in conjunction with each other to provide a bank erosion impact rating. The amount of erosion recorded is limited to what is observed during the windshield survey and does not represent the entire reach length. Therefore, the amount of erosion indicated in this step is underestimated. No reaches were rated as high for bank erosion (bank erosion observed along >20% of the reach length). Bank erosion was rated as low (bank erosion observed along >5% and <20% of the reach length) for four reaches within the Ompompanoosuc River Watershed (R03, R12.S1.04, R16, and R16T2.04). The remaining reaches accessed in this watershed during the windshield survey either had no erosion observed or were not significantly eroded (<5% bank erosion observed along the reach length).

Debris/Ice Jam Potential

Undersized culverts or bridges with spans less than the average channel width were the primary factors identified as potential for ice and debris jams. These structures, which are likely to cause constrictions during high flow events may result in lateral erosion or channel avulsions or may even endanger infrastructure.

In the Ompompanoosuc River Watershed, thirteen reaches had impact ratings of high (existing jams causing erosion and stream migration or history of jams and flooding for debris/ice-jam potential due to multiple causes). These reaches are located on the Ompompanoosuc main stem, West Branch Ompompanoosuc, Abbott Brook, Tributary one to Avery Brook, Barker Brook, and Middle Brook. Bridges located near the mouth of the Ompompanoosuc main stem are the primary concern for debris jams in the most downstream reach, R01. In the upper area of the main stem near the center of Vershire along Route 113, there are two reaches where there currently is evidence of debris jams (R27 and R28). The debris jam on R27 is not yet channel spanning, but in R28 there is a jam just downstream of the culvert at the Brown Road crossing. Also, near the Village of Post

Mills, there are areas of concern in reaches R15 and R16 due to multiple causes (bends, shallow bed, bridge, and debris). On the West Branch, there is an area of concern on the most downstream reach at the Route 132 Bridge near Rice Mills. Forty two reaches had a low impact rating (channel dimensions, pattern and profile indicate jams are possible). Four reaches were noted as having no significant jam potential (no noticeable sharp bends, narrow stream crossings, or wide shallow channel areas that may lead to jams).

6.0 PHASE 1 DATA ANALYSIS

6.1 Phase 1 Impact Scores

The impact scores for each Phase 1 step and total scores are reported on pages 25 through 27 of the Appendix. The Phase 1 Stream Geomorphic Assessment evaluates parameters that may cause channel adjustment. These parameters are grouped into four major categories: land use, in-stream modifications, floodplain modifications, and bed and bank windshield survey. Reach summary reports of these four categories are provided on pages 28 through 30 of the Appendix. Adjustment scores, reach condition, and reach sensitivity for all reaches are provided on pages 31 through 33 of the Appendix.

For each parameter, the maximum impact score for the Ompompanoosuc Watershed is 166 (83 reaches times impact score of 2). As shown below in Figure 8, the corridor land use and riparian buffers received the highest impact ratings for the watershed. The parameters watershed land use, channel straightening, berms and roads, river corridor development, meander belt width, average wavelength, and ice/debris jam potential also resulted in higher scores (>= 60).

The total impact scores (out of 32 possible) for the Phase I assessment for the main stem of the Ompompanoosuc River are summarized below in Figure 9. Reach R15 had the highest total impact rating of 23. This reach is downstream of a dam, has been straightened and armored considerably and is also impacted by the Route 113 Bridge, development and lack of buffer. In the Ompompanoosuc River Watershed, there were four reaches (R01, R02, R06, and R15) that received a Phase 1 reach condition of poor (Figure 10). These reaches are all located on the main stem of the Ompompanoosuc River. Three of the four reaches are located downstream of the Union Village Dam (located at upstream end of R06). R15 is located where Route 113 crosses the main stem in Post Mills. The impact scores for these reaches were high for channel straightening, bridges and culverts, and river corridor encroachment of roads and development. These reaches have undergone significant corridor land use/land cover, channel, and floodplain modifications which may have resulted in a change in planform, profile, and dimension such that the stream is no longer in balance with the flow and sediment regime of its watershed.

Thirty four reaches were assessed to be in fair condition. Streams in fair condition are likely to be undergoing adjustment and experiencing major and rapid changes due to recent floodplain and channel modifications, land cover changes, and/or loss of riparian buffer. The reaches in fair condition are located on the main stem of the Ompompanoosuc, Avery Brook, West Branch of the Ompompanoosuc, Abbott Brook, Barker Brook, Middle Brook, Blood Brook, and Tributary three to the Ompompanoosuc.

Reaches in good condition are thought to have experienced some degree of human-induced change to their watershed, floodplain and/or channel and are likely to be undergoing only minor adjustments. Twenty one reaches were in the good category. A reference reach has no significant channel or floodplain modifications and has a forested buffer, adjacent to the channel. In other words, these reaches are close to the natural condition. The remaining 24 reaches in the Ompompanoosuc River Watershed were in reference condition.

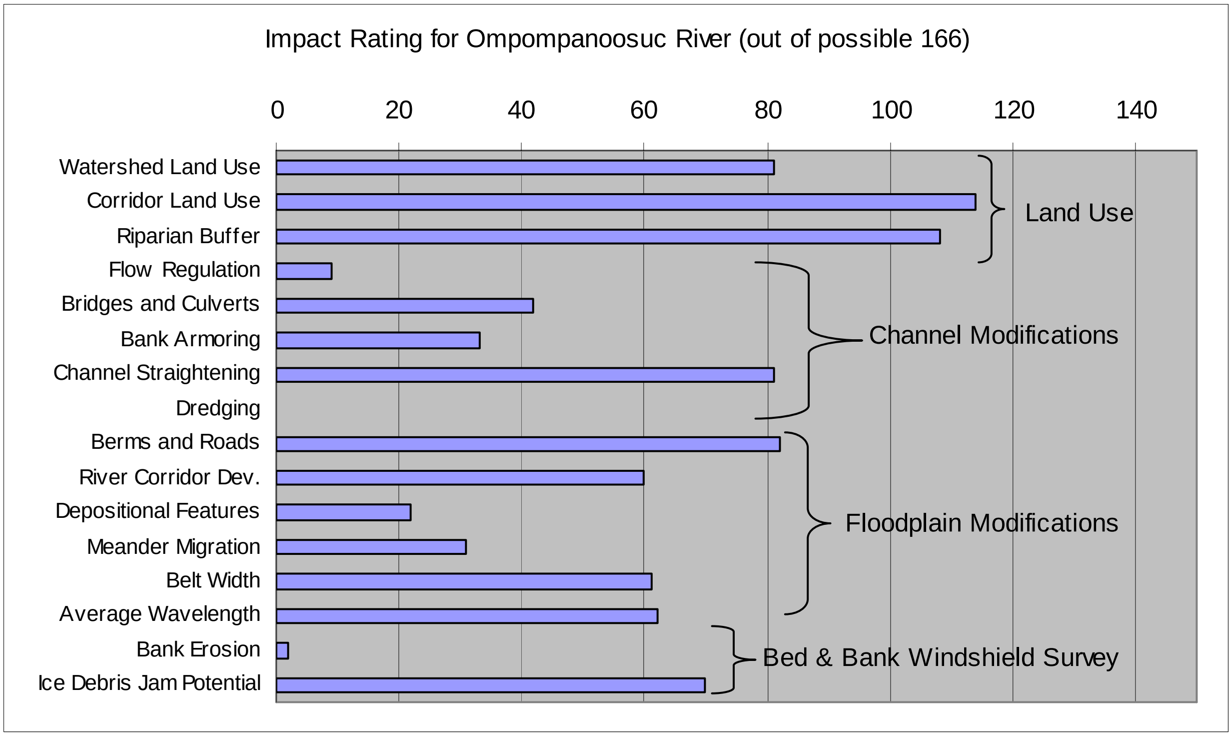

Figure 8: Impact Rating for Ompompanoosuc River Watershed by Parameter and Category

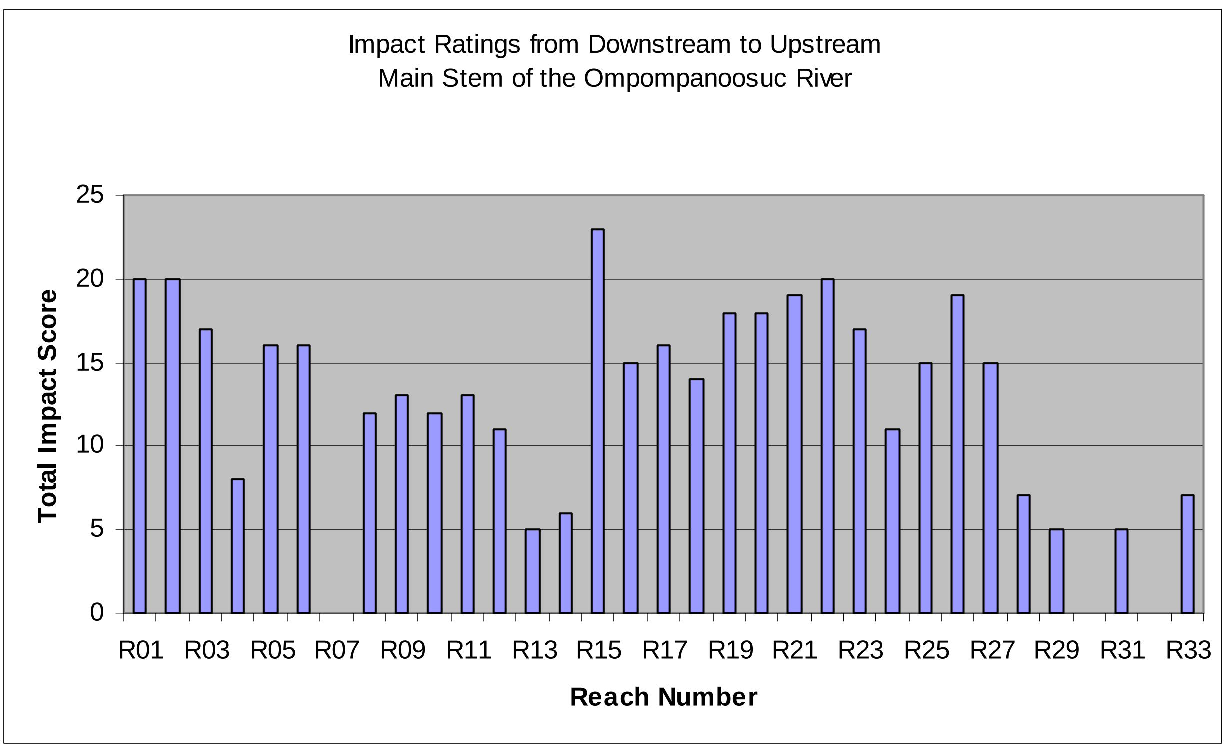

Figure 9: Impact Ratings (out of 32) from downstream to upstream on the main stem of the Ompompanoosuc River

6.2 Phase 1 Adjustment Processes

The Phase 1 data suggest that many of the stream reaches are experiencing more than one type of channel adjustment process. Based on the Phase 1 data, degradation, aggradation and planform adjustment were identified as the primary adjustment processes in some reaches in the Ompompanoosuc River Watershed. Most of these reaches were on the main stem of the Ompompanoosuc River both downstream from the Union Village Dam (R01, R02, and R06) and upstream from Brimstone Corner (R22, R25 and R26). R15, which is located at Route 132 crossing at Post Mills, also showed that degradation, aggradation and planform adjustment were the primary adjustment processes. The two most downstream reaches on the West Branch of the Ompompanoosuc (M01 and M02) also showed planform adjustment as the primary adjustment process.

6.3 Phase 1 Reach Sensitivity

The stream sensitivity is automated in the DMS based on the existing stream type and condition of each reach. Highly sensitive reaches are more likely to be in adjustment, and are very sensitive to land use changes within the watershed. Forty of the reaches received a high sensitivity rating. These reaches had valleys that were narrow to very broad. Thirty three reaches were classified as having a moderate reach sensitivity. Except for nine of the 33 reaches with moderate sensitivity, most of these reaches are narrowly confined, semi-confined, or narrow and have a "B" stream type that is less sensitive to change. Nine other reaches had a very low sensitivity. These reaches had narrowly confined valleys and a reference stream type of "A".

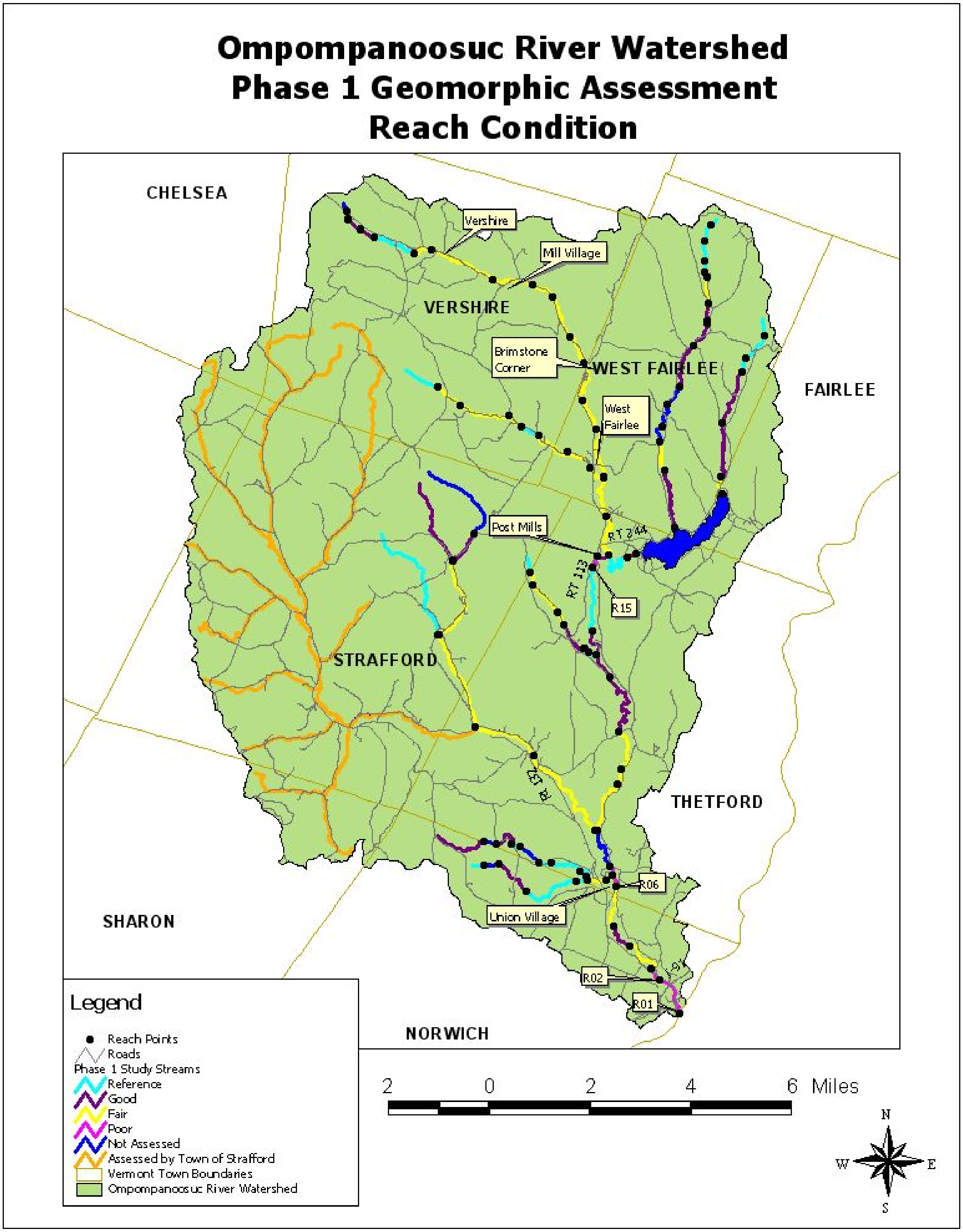

Figure 10: Reach Condition in the Ompompanoosuc River Watershed

7.0 CONCLUSIONS AND RECOMMENDATIONS

The Phase 1 Stream Geomorphic Assessment of the Ompompanoosuc River Watershed indicated that land use within the corridor, channel modification, and floodplain modification have been the greatest contributors to instability in the stream system. The majority of the reaches downstream from the Union Village Dam (located at upstream end of R06) and one reach further up in the watershed on the main stem (R15) are actively undergoing a process of major geomorphic adjustment. Many other reaches on the Ompompanoosuc River are also undergoing some significant geomorphic adjustment. These adjustments will likely continue to cause streambank erosion that is evidence of planform migration. As these processes unfold, habitat within the river may continue to be impacted. In this watershed, there has been some road encroachment into the floodplain that at this point is difficult to change due to the road infrastructure. However, wherever possible long term protection and restoration of the riparian corridor may help to improve habitat, water quality, and stream stability and to reduce the impact from such extensive floodplain encroachment.

The Phase 1 data are useful for prioritizing reaches for Phase 2 Geomorphic Assessment work. Phase 2 data provide information to pinpoint those areas where stream restoration would most benefit the aquatic and riparian habitat and long term geomorphic stability of the Ompompanoosuc Watershed. The most downstream reaches of the main stem of the Ompompanoosuc (R01 and R02) are not suitable for a full Phase 2 assessment because the channels are too wide and deep due to backwater influence from the Connecticut River. Due to the high level of observed impact and reach condition, reaches listed below and shown in Figure 11 are recommended for a Phase 2 assessment:

- Ompompanoosuc River – Twenty one reaches (R03 through R06, R08 through R27)
- Avery Brook – Two reaches (R06S1.01 and R06S1.02)
- Barker Brook –Three reaches (R12S1.05 through R12S1.07)
- Lake Fairlee outlet – Two reaches (R16T2.01 and R16T2.02)
- Middle Brook – Two reaches (R16T2.03S1.01 and R16T2.03S1.02)
- Blood Brook – Three reaches (R16T2.04 through R16T2.06)

- Tributary three to Ompompanoosuc – Seven reaches (R18T3.01 through R18T3.07)
- West Branch Ompompanoosuc – Two reaches (M01 and M02)
- Abbott Brook – Two reaches (T1.01 and T1.02)

A table providing the reach number, stream name, impact rating, reach condition, sensitivity rating, reach length in miles and the rationale for recommending that reach for a Phase 2 Assessment is provided on pages 34 and 35 of the Appendix. A total of 42.6 river miles have been recommended for additional stream geomorphic assessment work. The Phase 2 data serves as the bases for developing a River Corridor Management Plan. The implementation of a River Corridor Management Plan goes a long way towards reducing fluvial erosion hazards and minimizing land use conflicts. The River Corridor Management Plan would also provide structure for identifying river restoration and corridor protection project types.

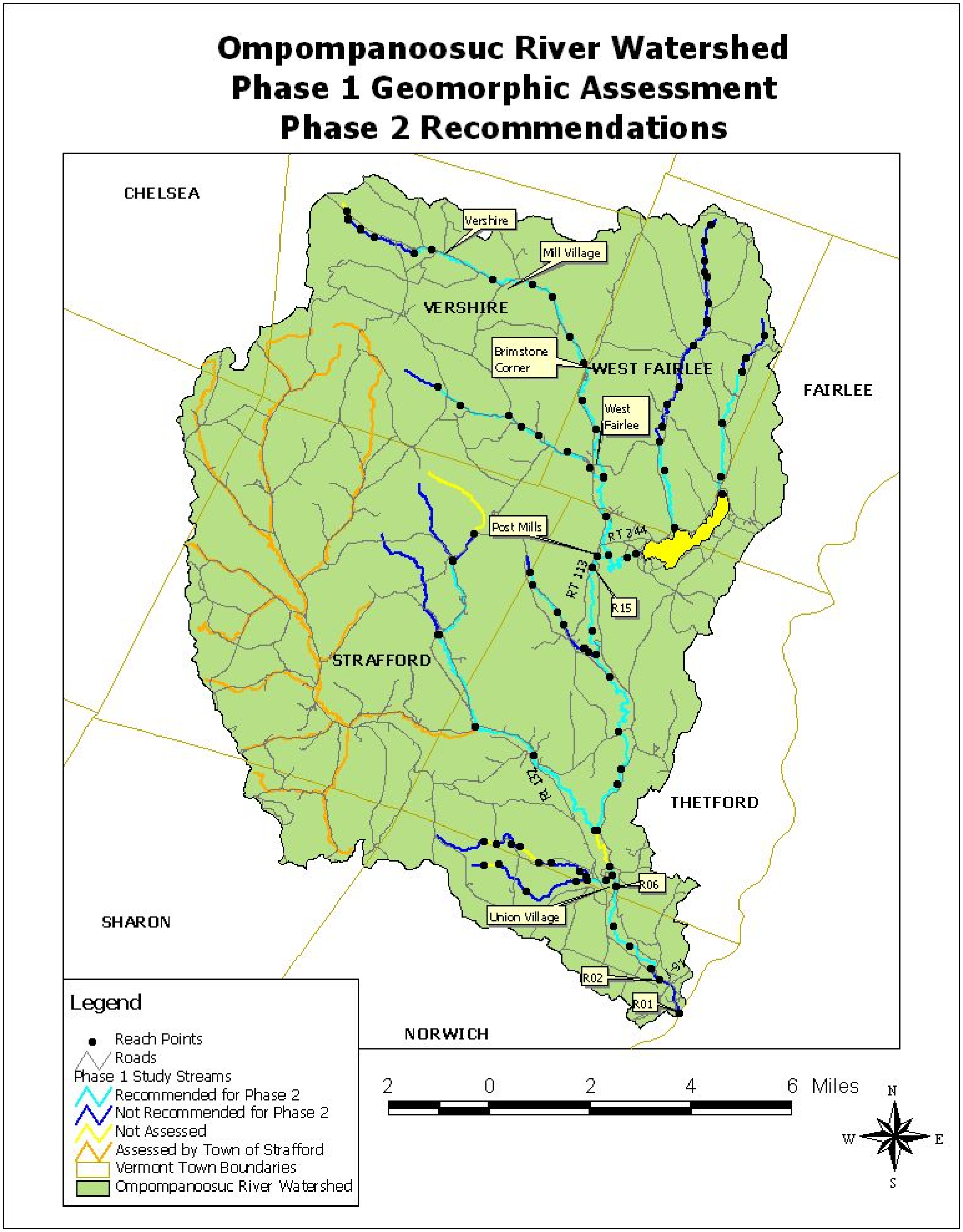

Figure 11: Recommendations for Phase 2 Geomorphic Assessment in the Ompompanoosuc River Watershed

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

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

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

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

Alluvial soils – Soil deposits from rivers.

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

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

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

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

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

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

Delta bar – A deposit of sediment where a tributary enters the mainstem of a river.

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

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.

Impact rating – The total of the impact scores for various Phase 1 parameters. Each Phase 1 parameter is assigned numeric values of 2, 1 and 0 for High, Low and Not Significant, respectively. The impact rating is used to red flag reaches that may be in adjustment and outside of the range of natural variability.

Lacustrine soils- Soil deposits from lakes.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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