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Phase 2 Stream Geomorphic Assessment
West Branch Little River Watershed
Town of Stowe
Lamoille County, Vermont

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TABLE OF CONTENTS

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EXECUTIVE SUMMARY

- The Lamoille County Planning Commission retained Bear Creek Environmental to perform a Phase 2 Geomorphic Assessment of six reaches on the West Branch Little River Watershed in the Town of Stowe.

- The Phase 2 study focused on six reaches on the main stem of the West Branch Little River from the confluence with the Little River, upstream to Ranch Brook.

- Protocols outlined in the Agency of Natural Resources, Stream Geomorphic Assessment, Phase 2 Handbook were employed. The Phase 2 data was entered into the most current version of the Phase 2 database.

- ArcView shapefiles were updated from the mapped field data for major parameters such as: bank erosion, bank revetments, and depositional features. New shapefiles were created for Phase 2 specific data such as cross-section locations, reach break locations, and photo points.

- The six phase 2 reaches were broken into nine segments to account for different stream types. Seven of the segments assessed for the Phase 2 study resulted in a geomorphic condition of fair. Two segments resulted in a geomorphic condition of poor.

- The Phase 2 Rapid Geomorphic Assessment (RGA) was used to evaluate the stage of channel evolution. Most of the segments assessed were found to be in Stage III of the Schumm Evolution model. These reaches were found to be in fair to poor condition, had undergone historical channel degradation, and were currently undergoing major to minor channel adjustments (e.g. channel widening, lateral migration, and aggradation). During Stage III, rivers typically exhibit significant bank failure. The Phase 2 assessment confirmed bank erosion is high within much of the main stem, as is channel armoring.

- In general, the Rapid Habitat Assessment (RHA) rating was similar to the RGA. Six of nine segments resulted in a rating of fair for the RHA. Three segments resulted in a rating of poor.

- A high percentage of the Phase 2 segments assessed during 2005 appear have departed from their reference as "C" channels and have become either "Bc" or "F" channels. Their reference stream type, "C", is characterized by the presence of point bars and other depositional features, and is very susceptible to shifts in both lateral and vertical stability caused by direct channel disturbance and changes in the flow and sediment regimes of the contributing watershed. Rates of lateral adjustment are influenced by the presence and condition of riparian vegetation (Rosgen 1996). For this reason, the acquisition of easements, streamside plantings, and buffer protection should be a high priority for restoration planning and design work.

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1.0 PROJECT OVERVIEW

A phase 1 stream geomorphic assessment of the West Branch Little River below the Ranch Brook confluence was completed during summer 2005 by the Lamoille County Planning Commission (LCPC). The Phase 2 assessment was completed by Bear Creek Environmental (BCE) during September and October 2005.

The West Branch Little River Watershed has a watershed size of 28 square miles just above the confluence of the Little River in the Town of Stowe, Vermont (Figure 1). The Phase 2 study focused on stream reaches on the main stem of the West Branch Little River within the Town of Stowe, from the confluence of the Little River to Ranch Brook (Reaches M3.01 through M3.06). The combined length of the stream reaches assessed is approximately 6 miles. A reach location map (Figure 2) is included below for reference.

The Phase 2 Geomorphic Assessment has been conducted to inform the community on the current and predicted adjustment processes of the West Branch River. The six reach assessments will be used by the LCPC to conduct a fluvial erosion hazard risk assessment and develop a fluvial erosion hazard (FEH) map that will comprehensively define high erosion hazard reaches along the West Branch main stem for the Town of Stowe.

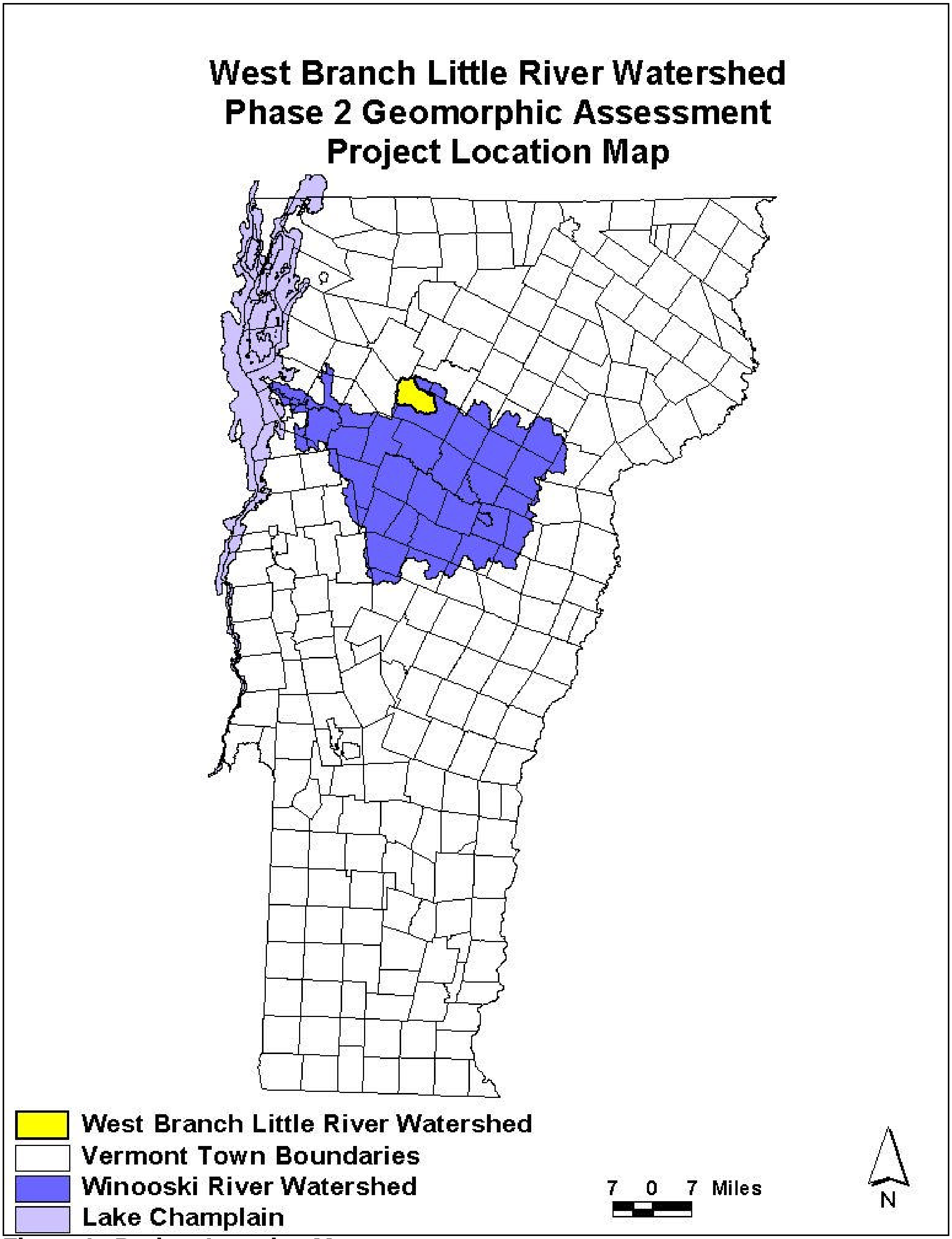

Figure 1. Project Location Map

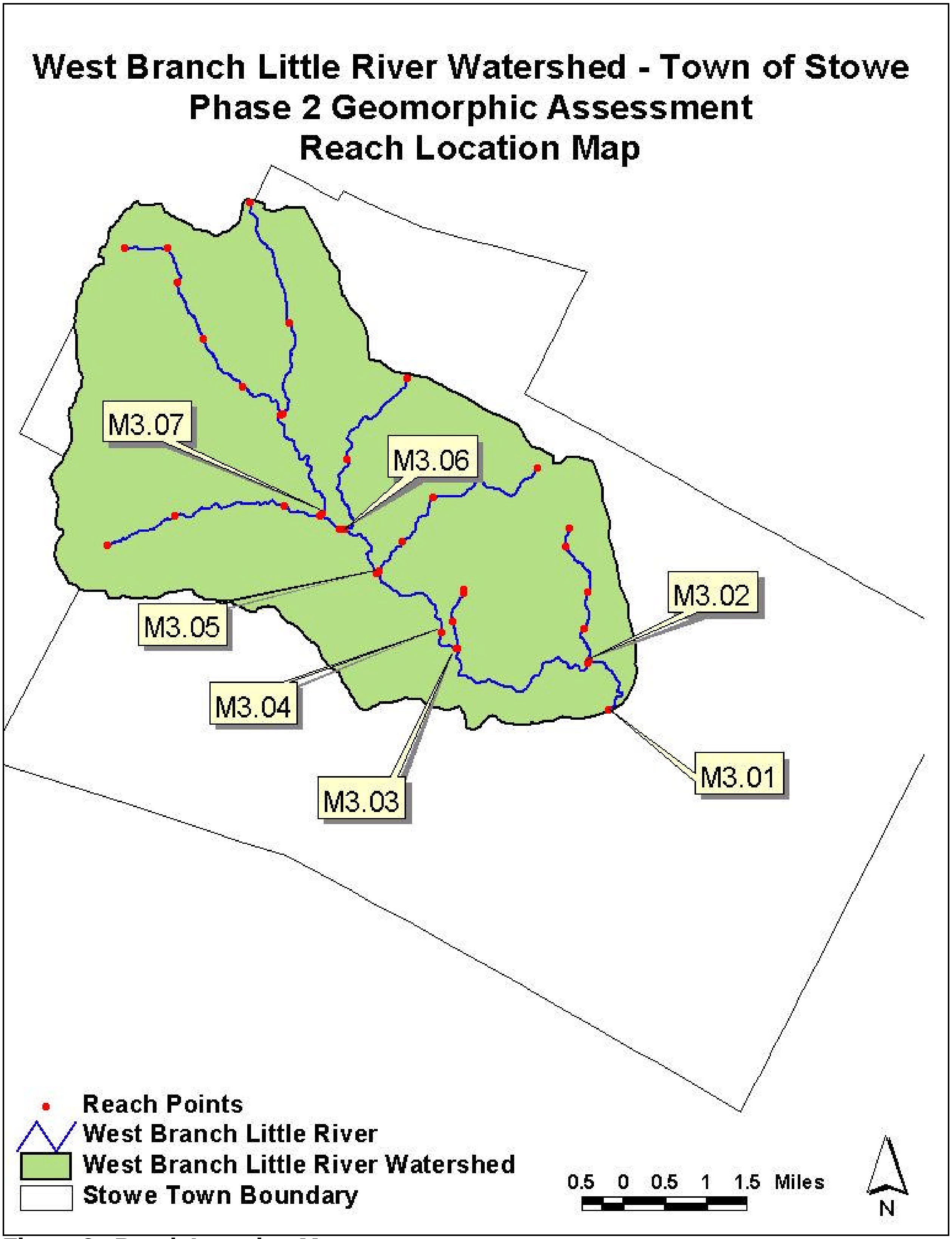

Figure 2. Reach Location Map

2.0 BACKGROUND INFORMATION

2.1 Description of Study Area

BCE was contracted to conduct Phase 2 Assessments on 6 reaches of the West Branch watershed from the confluence with the Little River upstream to Ranch Brook. The West Branch of the Little River watershed is a 27.7 square mile watershed in Lamoille County, Vermont. The West Branch flows south and joins the Little River, and then the Winooski River which drains westerly into Lake Champlain.

The West Branch drains from the highest point in Vermont, the summit of Mount Mansfield, 4393 feet, to the confluence with the Little River at approximately 700 feet above sea level. From Ranch Brook to the Little River the West Branch has an average slope of 0.8 percent.

2.2 Flood History

The West Branch watershed averages 53 inches of precipitation annually. Mount Mansfield creates an orographic[1] effect, and therefore receives higher precipitation than most areas in Vermont. The majority of floods in the West Branch have occurred during the summer months and are associated with large cloudbursts, which stay in the mountains producing high rainfall amounts. The most recent such event occurred on July 12, 2004 costing $800K in property damage (NCDC 2005). The remaining large floods are divided equally between fall and winter/spring. The fall flood events are often associated with hurricanes. Winter/spring floods are often associated with saturated soils from rain or snowmelt (Barg, 2004)

3.0 METHODOLOGY

The Phase 2 assessment followed procedures specified in the Vermont Stream Geomorphic Assessment Handbook Phase 2 (ANR 2005). All assessment data were recorded on the Agency of Natural Resources Phase 2 data sheets, and were entered in to the ANR Stream

[1] Rainfall amounts dramatically increase on the windward side of a mountain

Geomorphic Assessment data management system (DMS). The Phase 1 database was updated using the field data from the Phase 2 assessment.

3.1 Field Protocols

The ANR's Phase 2 stream geomorphic assessment protocol includes seven categories of investigation. These categories are as follows:

1. Valley and River Corridor
2. Stream Channel
3. Riparian Banks, Buffers and Corridor
4. Flow Modifiers
5. Channel, Bed and Planform Changes
6. Rapid Habitat Assessment (RHA)
7. Rapid Geomorphic Assessment (RGA)

The parameters and protocols used for undertaking each of the above steps are outlined in the Phase 2 Handbook (Vermont Agency of Natural Resources, 2005). The entire length of each Phase 2 reach was walked to determine segment breaks. Bank erosion, grade control structures, bank revetments, debris jams, depositional features, stormwater inputs, flood chutes and other important features were mapped within all segments.

3.2 Quality Assurance (QA) Review

Bear Creek Environmental performed a thorough in-house QA review of the Phase 2 data. The DMS and the ArcView Shapefiles for the West Branch Little River Phase 2 study were submitted to Peter Spatz of the ANR for a QA review in October 2005. Peter Spatz completed the QA review on October 28, 2005.

4.0 RESULTS

Phase 2 Reach Summary Reports from the DMS are included on pages 1 through 18 of Appendix A. The Stream Geometry Data Report is found on pages 19 of Appendix A, while page 20 of Appendix A provides the Rapid Geomorphic Summary Report. The results of the Phase 2 study are discussed below by reach number.

4.1 Reach M3.01

Reach M3.01 has undergone a stream type departure from a C channel to a B channel due to historic incision. The current incision ratio was calculated to be 2.3, suggesting the incision process has reduced the flood prone area of this reach creating a channel that has lost access to most of its historic floodplain. This reach is exhibiting signs of active channel adjustment as it is now working to recreate a lower floodplain area through planform adjustment, widening and aggradation.

Figure 3. M3.01 has lost access to its floodplain. It is currently exhibiting active planform adjustment and widening as it works to create a new lower floodplain bench.

Substrates in reach M3.01 were recorded to be soft underfoot and about 50 percent of the particles were comprised of sand and fine gravel. Sediment storage bars included mid channel, point, diagonal, and side bars. These bars are prevalent as the stream works to rebuild new floodplain areas and eventually will begin to narrow its channel.

Active adjustment was evident through erosion which was prevalent in this section. Approximately 50 percent of the left and right banks had moderate to severe bank erosion (Figure 3). Where active erosion was absent, riprap often covered the banks. In one area, riprap was found crossing the middle of the channel, thereby marking the historic location of the river and creating evidence of lateral migration (Figure 4). Hay fields were noted to be the dominant land use within the riparian corridor of reach M3.01. The buffer was narrow on both sides (<25 feet in width) with lots of invasive Japanese knotweed. Herbaceous vegetation was the dominant vegetation type.

Figure 4. Planform adjustment is evident in this photograph of M3.01 where an attempt to riprap this actively moving channel had failed leaving the riprap cutting from a bar across the channel to the far bank.

4.2 Reach M3.02

Reach M3.02 begins just above Weeks Hill Road and continues until the confluence of M3.T2.01. This reach is located in a very broad valley that was once accessed by the

West Branch River. This reach, however, has also undergone historic incision (Figure 5). Information recorded at one typical cross section rated the incision ratio to currently be 1.92. The reach is actively working to recreate a new floodplain at a lower elevation and is doing so by migrating laterally and scouring its banks.

Figure 5. High abandoned terraces along reach M3.02 help show the historic incision that has occurred on this reach. The second terrace (behind and above the field scientist) is a flat agricultural field that was at one time the floodplain of the West Branch.

Extensive lateral bank erosion was observed in reach M3.02 on most outside bends, as shown in Figure 6. Based on the high lateral bank erosion and the historic and active flood chutes, reach M3.02 appears to undergoing major planform adjustment and widening.

The riparian corridor of reach M3.02 was dominated by commercial and residential activities. The buffer width ranged between 5 and 50 feet wide with deciduous trees dominating. Riprap has been used extensively along this reach, it is found along approximately 40% of each bank through the entire two-mile long reach.

Figure 6. Reach M3.02 is actively undergoing planform adjustment. As illustrated in this photograph, the river is migrating into its left bank causing trees to fall into the river.

Among two channel bridges that constrict the channel of reach M3.02, Luce Hill Bridge is perhaps most noteworthy for its affect on sediment transport on the West Branch. As seen in Figure 7, Luce Hill Bridge is only 30 feet wide at its base, thereby causing major upstream deposition of sediment and scour in the area downstream of the bridge.

4.3 Reach M3.03

Reach M3.03 was segmented because of change in the entrenchment ratio, which resulted in a different stream type.

Figure 7. Luce Hill Road Bridge, a channel constriction that locally disrupts the sediment transport of the West Branch within Reach M3.02.

Segment M3.03-A

Segment M3.03-A was historically a slightly entrenched, riffle-pool stream. Encroachments from Route 108 and past channel management activities have caused this segment to become incised, overwide and featureless as shown in Figure 8. BCE and ANR scientists recorded the incision ratio to be 2.47. The river lacks access to an adequate floodplain through this reach and has therefore become an “F” type stream channel with a plane bed form. There is very little sediment storage within this segment. Bank erosion would likely be more severe if the left bank had not been rip-rapped along most of the segment.

Figure 8. Floodplain encroachment from Route 108 along with historic incision has created an "F" channel along segment M3.03-A. Note the plane bed bedform and high width to depth ratio.

Segment M3.03-B

Reach M3.03-B, like many on the West Branch, has been impacted by channel incision and floodplain encroachment. The river is further along in channel evolution than its downstream segment M3.03-A, having reestablished a small floodplain bench and begun to develop point bars (see Figure 9). It remains relatively wide and shallow, however, and is a moderately entrenched "B" type channel that is dominated by plane bed features.

Figure 9. This photograph shows a typical cross-section along segment M3.03-B. The stream has worked to create a small bench on the right bank and is now only moderately entrenched.

4.4 Reach M3.04

Reach M3.04 was broken into three segments to account for different stream types.

Segment M3.04-A

Segment M3.04-A, also has been impacted by channel incision and floodplain encroachment. The river is far along in the channel evolution model (stage IV), having reestablished a small floodplain bench and begun to develop bars. However, it remains wide and shallow (see Figure 10), and is a moderately entrenched "B" type channel that is dominated by plane bed features. The current incision ratio was measured to be 2.86.

The reach is actively responding to sediment which is being stored in the form of mid, point, side, and diagonal bars. Several active flood chutes were noted along this reach.

Route 108 and the Stowe bike path both have encroached on the historic floodplain of this reach. The current riparian corridor is dominated by commercial buildings on the left bank and crop fields on the right. The left bank would benefit from riparian buffer planting as it is dominated by only a 5-25 foot wide buffer.

Figure 10. Reach M3.04-A is typically wide and shallow. The stream has only a small floodplain along most of the reach and is actively undergoing planform adjustment to try and reestablish a floodplain bench.

Segment M3.04-B

Segment M3.04-B is a highly entrenched. The incision ratio through this reach was calculated to be 3.6. After the channel incised it widened to its current condition, an "F" type channel that has lost its riffle-pool bedform (Figure 11). There is high bank erosion, 50%, on the left bank, however there is still very little sediment storage occurring along this reach. As shown in Figure 12, the riparian corridor is dominated by a fairly healthy forested buffer along most of the reach. This healthy mix of trees has probably slowed planform adjustment and widening along this reach, which would help to explain why it is still an "F" type channel despite the very limited floodplain encroachment.

Figure 11. Segment M3.03-B has incised. It is an "F" channel with plane bed characteristics.

Figure 12. Photograph depicting level of incision at segment M3.04-B

Segment M3.04-C

Segment M3.04-C was not as incised as many of the other reaches surveyed in this study. With a recorded incision ratio of 1.52, segment M3.04-C was moderately incised, however, had not lost access to all of its floodplain (see Figure 13). Although moderately entrenched, the river in this segment is still a "C" channel with weak riffle-pool features. BCE recorded major historic degradation and active planform changes as the major adjustment processes affecting this reach. Signs of bed aggradation and sediment storage were evident in the mid, point, and side bars found within this reach. There was one active flood chute suggesting some potential planform change.

The riparian conditions of this reach were good and it was the first reach where BCE scientists noted many fish utilizing the instream habitat. The riparian corridor was 100 feet wide along most of the reach and was a mix of deciduous and coniferous trees.

Figure 13. Here at M3.04-C, the stream is less incised and therefore has low entrenchment as a C channel.

4.5 Reach M3.05

Reach M3.05 was a highly active reach in terms of planform adjustment (see Figure 14). There were numerous active flood chutes (one about to form a permanent island) that the river had been accessing during high flow events. This reach was also very responsive to sediment and has been storing it in the form of large point and side bars.

Reach M3.05 had a relatively low incision ratio of 1.24 and was found to have remained, or have evolved back to a "C" channel despite evidence of historic incision. It retains a weak riffle-pool bedform that had low amounts of sand and fine gravel. The major riparian corridor land uses in this reach are commercial and residential structures. In some areas these structures, along with Route 108 and Brook Road have encroached upon the belt width of the river. However, in general there is a healthy riparian forest protecting this reach and it seems to have enough room to undergo the lateral migration that it needs to reestablish a dynamic equilibrium.

Figure 14. Reach M3.05 is undergoing active planform adjustment. A flood chute cuts across the inside of this meander (right bank) as the river migrates left causing trees to fall into the river.

4.6 Reach M3.06

The uppermost reach of this study, M3.06 is draining a watershed area of 14.71 square miles. Evaluated in the phase 1 study to be a “C” type channel, this reach was found to be a moderately entrenched “F” type channel. As shown in Figure 15, historic degradation, floodplain encroachment, and channel straightening have affected this reach greatly. It was found to be a plane bed channel that had very little sediment storage capacity.

Figure 15. Reach M3.06 has seen historic straightening and floodplain encroachment and is now an entrenched “F” stream type with plane bed morphology.

5.0 GEOMORPHIC CONDITION

Understanding the response to changes in the sediment regime, hydrology, and channel of the West Branch is highly useful for informing restoration efforts.

5.1 Channel Management History

Natural and anthropogenic impacts alter the delicate equilibrium of sediment and discharge in natural stream systems and set in motion a series of morphological responses as the channel tries to reestablish equilibrium. Small to moderate changes in slope, discharge or sediment supply can alter grain size and channel geometry; while large changes can transform reach level channel types (Ryan 2001). Human-induced practices that have contributed to stream instability within the West Branch watershed include:

- Gravel mining
- Channelization
- Alteration of woody riparian vegetation
- Floodplain encroachments
- Urbanization
- Poor road maintenance practice and infrastructure installation

These anthropogenic practices have altered the delicate balance between water and sediment discharges. Channel morphologic responses to these practices contribute to channel bed degradation and/or aggradation that further create unstable channels. These morphologic changes tend to migrate both upstream and downstream contributing to system-wide instability. (Ryan 2001)

5.2 Channel Evolution

The quantity of sediment and sediment size is proportional to the slope of the stream and the amount of water the stream is discharging. A change in any one of these variables will result in a corresponding change in the other variables to achieve equilibrium. A large change in one of these variables will be followed by channel evolution as the stream works to regain equilibrium. According to Schumm's channel evolution model (see Appendix B), the stages of channel evolution include:

- A pre-disturbance period
- Incision – Channel degradation and headcutting
- Aggradation and channel widening

- The gradual formation of a stable channel with access to its flood plain at a lower base elevation.

The West Branch of the Little River is undergoing this channel evolution process in response to large scale changes in its sediment, slope, and/or discharge associated with the human influences on the watershed. Table 1 refers to the channel evolution of each study reach.

Table 1. Stream Type and Channel Evolution Stage

Segment Number	Entrenchment Ratio	Width to Depth Ratio	Reference Stream Type	Existing Stream Type	Channel Evolution Stage	Major Active Adjustment Process
M3.01	1.9	31	C	B4c	III	Aggradation Widening Planform
M3.02	3.9	20	C	C4	IV	Aggradation Planform
M3.03-A	1.2	24	C	F3	II	Aggradation
M3.03-B	1.6	24	C	B4c	III	Aggradation Widening
M3.04-A	1.5	43	C	B4c	IV	Aggradation Widening Planform
M3.04-B	1.4	26	C	F4	II	Aggradation Widening
M3.04-C	2.5	25	C	C4	IV	Aggradation Planform
M3.05	3.5	25	C	C3	IV	Planform
M3.06	1.5	27	C	F3b	II	Aggradation Widening

In terms of the channel evolution model, the West Branch of the Little River main stem generally appears to be between stages II and IV in the channel evolution model (see Appendix B). The channel has undergone historic degradation, and the system is regaining equilibrium by moving laterally and widening. Aggradation is likely associated with widening as the stream has increased sediment load from eroding banks and becomes too wide to effectively transport its bedload. Bank erosion is prevalent, particularly on the outside meander bends as the channel moves to rebuild the floodplain. Unvegetated mid channel bars and side bars confirm the channel is undergoing extensive lateral migration. As sinuosity increases, the channel slope decreases. Active flood chutes are another indication that the main channel is shifting back and forth as the terrace side slopes erode.

All of the cross sections on study reaches were found to be incised. The incision ratio ranged form 1.24 to 3.58. Six of the nine cross sections were found to have a bankfull elevation that was at least one mean bankfull depth lower than the top of the low bank. These reaches are actively undergoing channel widening and planform adjustment as they try to reestablish a new floodplain at a lower elevation.

5.3 Stream Sensitivity

Sensitivity refers to the likelihood that a stream will respond to a watershed or local disturbance or stressor, such as; floodplain encroachment, channel straightening or armoring, changes in sediment or flow inputs, and/or disturbance of riparian vegetation. Stream sensitivity ratings are assigned based on predictable responses related to stream type and substrates. Streams that are currently in adjustment, especially those undergoing degradation or aggradation, may become acutely sensitive (ANR 2004). Table 2 describes the sensitivity rating of the studied reaches.

Table 2. Stream Sensitivity for Phase 2 Reaches

Segment Number	Existing Stream Type	Stream Type Departure	Sensitivity
M3.01	B4c	Yes	Very High
M3.02	C4	No	Very High
M3.03-A	F3	Yes	Extreme
M3.03-B	B4c	Yes	Very High
M3.04-A	B4c	Yes	Very High
M3.04-B	F4	Yes	Extreme

Table 2. Stream Sensitivity for Phase 2 Reaches			
Segment Number	**Existing Stream Type**	**Stream Type Departure**	**Sensitivity**
M3.04-C	C4	No	Very High
M3.05	C3	No	High
M3.06	F3b	Yes	Extreme

6.0 HABITAT EVALUATION

Table 3 below shows a comparison of the habitat condition based on the RHA and the geomorphic condition based on the RGA. For six of the nine segments, both the RHA and the RGA resulted in ratings of fair. Reach M3.01 and M3.04-A had a rating of poor for both habitat and geomorphic condition. Segment M3.04-B had a rating of poor for habitat, but a rating of fair for geomorphic condition. No segments resulted in a rating of good for either geomorphic and habitat condition, although it was noted in the field by BCE scientist that segment M3.04-B had good riparian conditions and many fish were utilizing the instream cover. Instream cover within segment M3.04-B included large boulders, tree roots and depth cover in a few pools, most of which were well shaded by a healthy riparian corridor. In general the study reaches lacked a strong riffle-pool bedform (many were plane bed) and the diversity of habitat features that this brings. Additionally, sediment contributions of sand and fine gravel from the watershed, as well as localized contributions from banks that were eroding as the river adjusts, have created an embedded river bottom along much of the study area. Most reaches had significant intrusion into their river corridor and lacked adequate riparian buffers. Overall, the RHA score was similar to the RGA score, implying that the ecological health of the West Branch of the Little River is intricately tied to the geomorphic condition of the stream.

Table 3. Comparison of RHA and RGA for Phase 2 Reaches		
Segment Number	**Rating RHA**	**Rating RGA**
M3.01	Poor	Poor
M3.02	Fair	Fair

Table 3. Comparison of RHA and RGA for Phase 2 Reaches

Segment Number	Rating RHA	Rating RGA
M3.03-A	Fair	Fair
M3.03-B	Fair	Fair
M3.04-A	Poor	Poor
M3.04-B	Fair	Poor
M3.04-C	Fair	Fair
M3.05	Fair	Fair
M3.06	Fair	Fair

7.0 RECOMMENDATIONS

Based on the Phase 2 Assessment performed during 2005, Bear Creek Environmental recommends the following:

1. Carefully consider the stream evolution and sensitivity before conducting any active geomorphic restoration projects in the main channel of the West Branch.

2. Perform a Phase 2 assessment of the mainstem above reach M06 to determine if these reaches are undergoing adjustment. This would provide additional information for restoration design and planning.

3. Perform a Phase 2 assessment of the major tributaries, many of which appear to have been altered and are rejuvenating at the mouths, to determine if these reaches are undergoing adjustment.

4. The reference stream type for much of the mainstem of the West Branch Little between the Stowe town line appears to be “C”. C type stream channels are highly dependent upon vegetation for stability. For this reason, the establishment and protection of vegetated buffers should be high priority in restoration planning and design work. Riparian buffers provide many benefits. Some of these benefits are protecting and enhancing water quality, providing fish and wildlife habitat, providing streamside shading, and providing root structure to prevent bank erosion.

5. The Lamoille County Planning Commission has recently received a River Corridor Development Grant for the ANR to develop a river corridor protection plan. The implementation of a river corridor protection plan goes a long way towards toward reducing fluvial erosion hazards and minimizing land use conflicts. As a starting point,

fluvial geomorphic relationships can be used to determine the width of a river corridor which is needed to accommodate the meander geometry under equilibrium conditions. As discussed in the Defining River Corridors Fact Sheet, prepared by the Vermont DEC River Management Programs, rivers with gentle gradients and narrow to broad valleys require a meander belt width of 6 times the channel width to accommodate the meanders. At the lowest end of the Phase 2 study area, this equates to a meander belt width of 414 feet (or approximately 207 feet on each side of the meander center line).

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