Bear Creek Environmental

Phase 1 and 2 Stream Geomorphic Assessments

North Branch of Deerfield River Watershed

Windham County, Vermont

Final Report
January 30, 2006

297 East Bear Swamp Road
Middlesex, Vermont 05602
Phone: (802) 223-5140
Fax: (802) 229-4410
email: bearcrk@sover.net

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Phone: (802) 223-5140 / **Fax:** (802) 229-4410

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Prepared by:

Michael Blazewicz
Environmental Scientist

Pamela DeAndrea
GIS Specialist

And

Mary Nealon
Principal/River Scientist

Prepared for:

Vermont Department of Environmental Conservation
Water Quality Division
103 South Main Street
Building 10 North
Waterbury, VT 05671-0408

Bear Creek **Environmental**
297 East Bear Swamp Road, Middlesex, Vermont 05602
Phone: (802) 223-5140 / **Fax:** (802) 229-4410

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Bear Creek Environmental (BCE) would like to thank several individuals for assisting with the Phase 1 and 2 Geomorphic Assessments of the North Branch of the Deerfield River Watershed. We thank Shannon Hill of the Vermont Department of Environmental Conservation (VDEC) for assisting with field data collection and for providing technical expertise. We would like to acknowledge Shannon Hill, Jim Pease (VDEC), and Jennifer Callahan (VDEC) for providing review comments on the draft report. We express gratitude to Brian Fritzgerald and Fred Nicholson of the VDEC for providing information relating to flow regulations and channel modifications, respectively, within the North Branch of the Deerfield watershed. Lana Palumbo and Susan Haghwout (Town of Wilmington) and Mary Lou Raymo (Town of West Dover) provided useful information about the development and flood history of the watershed. The BCE project team is also grateful to the riparian landowners within the North Branch of the Deerfield River Watershed for granting us access to our study reaches.

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EXECUTIVE SUMMARY

Phase I and 2 Stream Geomorphic Assessments of the North Branch of the Deerfield River watershed were completed by Bear Creek Environmental during summer 2005. These stream geomorphic assessments provide information about the physical condition of streams within the watershed and the factors that influence their stability. The project was funded through the Vermont Clean and Clear Program. The Stormwater Section of the Vermont Department of Environmental Conservation (DEC) sponsored the project, and the DEC River Management Program provided technical expertise and shared quality control/quality assurance responsibilities with Bear Creek Environmental. The Phase 1 study included the North Branch of the Deerfield River and major tributaries: Binney Brook, Beaver Brook, Cold Brook, Bill Brook, Hall Brook, Ellis Brook and Blue Brook. The Phase 2 study focused on stream reaches on the main stem of the North Branch from the confluence of the Deerfield River, upstream past the Mount Snow Resort.

The study followed the Phase 1 and 2 assessment protocols developed by the DEC River Management Program. Information from the study came from the DEC, the Vermont Mapping Program, the Vermont Center for Geographic Information, the Towns of Wilmington and Dover and field data collected by Bear Creek Environmental. The Phase 1 study used a combination of remote sensing (i.e. mapping) and windshield surveys to understand the stream's response to natural and human disturbances that have influenced the North Branch of the Deerfield River watershed. As part of the Phase 1 study, the watershed was divided into 48 reaches based on confinement, slope, soils, and tributary influence. The Phase 2 Rapid Stream Assessment included field observations and measurements that are used to verify the Phase 1 stream geomorphic data and provide field evidence of channel adjustment processes and habitat quality of the study reaches.

The focus of the Phase 1 study is to evaluate parameters that may cause channel adjustment such as floodplain modifications, channel modifications, and land use. Of the four impact categories measured during the Phase 1 Assessment, floodplain modification was the category identified as having the greatest potential to cause channel adjustment in the North Branch River watershed. Forty-six percent of the reaches resulted in an impact rating of high for berms and roads and 25 percent for corridor development. Land use was also identified as a potential cause for channel adjustment in the North Branch watershed. River corridor land cover/land use received an impact rating of high for 54 percent of the stream reaches. In-stream channel modification received high impact ratings flow regulation, bank armoring, channel straightening and dredging history. The meander migration, meander width ratio, and meander wavelength are a sign that some reaches are in adjustment. Meander width ratios measured on the North Branch indicate the river has become straighter and steeper, resulting in degradation and loss of access to its floodplain.

The Phase 2 data assessment focused on data collection relating to the stream channel, the riparian corridor, and aquatic habitat. This information can be used in watershed planning, for the establishment of erosion hazard zones, and for the identification of watershed improvement projects. The Phase 2 assessment consists of field notes, documentation of reach conditions through mapping and photography, and the completion of a Rapid Geomorphic Assessment (RGA) and Rapid Habitat Assessment (RHA).

The Phase 2 Rapid Geomorphic Assessment (RGA) is important for understanding the geomorphic stability of a reach. The RGA includes an evaluation of reach condition (departure from reference condition), channel adjustment process, and the reach sensitivity. The reach condition describes the degree of departure of the channel from its reference stream type. The channel adjustment process is a change in the form of the channel due to natural causes or human impacts. Reach sensitivity describes how sensitive a stream reach is to changes within the watershed, and is dependent upon the existing stream type and the condition of the reach.

Only two of the nineteen reaches included in the Phase 2 assessment resulted in a geomorphic condition of reference. Two segments resulted in a geomorphic condition of good. The majority, fourteen of the segments assessed resulted in a geomorphic condition of fair. One segment, in the Village of West Dover, resulted in a 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 ANR F-Stage Channel Evolution model. These reaches were generally found to be in fair condition, had undergone historical channel degradation and were currently undergoing major to minor channel adjustments (e.g. channel widening, planform adjustment, and aggradation).

The Rapid Habitat Assessment (RHA) is used to evaluate the physical components of a stream (the channel bed, banks, and riparian vegetation) and how the physical condition of the stream affects aquatic life. The results can be used to compare physical habitat condition between sites, streams, or watersheds, and also serve as a management tool in watershed planning or similar land-use planning. In general, the Rapid Habitat Assessment (RHA) rating was similar to the RGA. Two of the nineteen segments resulted in a reference habitat rating. Fifteen of nineteen segments resulted in a rating of fair for the RHA. Two segments resulted in a poor rating for habitat.

A high percentage of the Phase 2 segments assessed during 2005 appear have departed from their reference as "C" channels and have become either "F" or "Bc" 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. For this reason, the acquisition of easements, streamside plantings, and buffer protection should be a high priority for restoration planning and design work.

In summary, the Phase 1 and 2 stream assessments identified several important stressors to geomorphic condition within the North Branch watershed. Lack of riparian buffers, floodplain encroachment, and channel straightening were identified as primary factors influencing the geomorphic condition of the main stem. In addition, stormwater runoff and the influence of Snow Lake have both altered the hydrology and sediment regime of the watershed. Recommendations for improvements within the North Branch watershed are provided at the end of this report.

Bear Creek Environmental
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Phone: (802) 223-5140 / Fax: (802) 229-4410

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SECTION 1: PROJECT OVERVIEW AND BACKGROUND

1.1 PROJECT OVERVIEW

Bear Creek Environmental was retained by the Vermont Department of Environmental Conservation (VDEC) to conduct Phase 1 and Phase 2 Stream Geomorphic Assessments within the North Branch of the Deerfield River (North Branch) watershed. The North Branch watershed is located primarily in the Towns of Wilmington and Dover (Figure 1). The Phase 1 assessment was completed on the North Branch and major tributaries[1]: Binney Brook, Beaver Brook, Cold Brook, Bill Brook, Hall Brook, Ellis Brook and Blue Brook (Figure 2). The Phase 2 assessment was conducted on the entire mainstem of the North Branch. Reaches with onstream ponds were excluded from the assessment.

The North Branch from Tannery Road to 0.2 miles upstream of Snow Lake is listed on the 2004 State of Vermont 303(d) list of impaired waters (Figure 3). Both aesthetics and aquatic life support are existing uses that are not supported in the impaired segment of the river. The main objectives of the Phase 1 study were to provide an overview of the general physical characteristics of the watershed, assess the impacts of parameters such as land use, channel modification, floodplain modification, erosion and debris/ice-jam potential on each reach, and to determine which reaches may be in channel adjustment. The primary objective of the Phase 2

[1] Per the ANR protocols major tributaries constitute ten percent or more of the watershed area at the confluence with the main stem.

Assessment was to provide the VDEC with information that can be used for watershed planning and restoration activities.

Data and information for the North Branch watershed was obtained from the VDEC and the Vermont Center for Geographic Information (VCGI). Windshield surveys of the watershed were conducted on July 18 and 19, 2005. Mary Nealon, Michael Blazewicz, and Alyssa Borowske of Bear Creek Environmental conducted the majority of the Phase 2 assessments reaches between August 1 and 11, 2005. Shannon Hill of the VDEC assisted with the Phase 2 field data collection of the reach located immediately downstream of Snow Lake.

As part of the public outreach component of the project, representatives of Mount Snow Resort and the Town of West Dover were informed of the stream geomorphic assessment within the North Branch watershed and were invited to participate in the Phase 2 fieldwork. Tom Montemagni and John Mulhall of Mount Snow and Gary Curruthers, road foreman in West Dover, were contacted by Michael Blazewicz in early August 2005.

1.2 BACKGROUND INFORMATION

1.2.1 Description of Study Area

The North Branch is a main tributary to the Deerfield River and has a watershed size of 56 square miles (Figure 1). The watershed outlet lies just west of the town of Wilmington at the north end of the Harriman Reservoir. The Deerfield River then continues to flow to the Connecticut River in Massachusetts. With the exception of the reaches in the headwaters, the main stem of the North Branch flows through a valley with a gentle to moderate gradient.

The North Branch watershed is located east of the Green Mountains in southern Vermont. This area is composed of Precambrian gneiss part of the Green Mountain massif (Van Diver, 1987). A serpentine belt is located in the watershed within greatly sheared and folded schist with thrust faults that border the Green Mountain massif (Van

Diver, 1987). The dominant soil types in the North Branch watershed are alluvium, glacial till and ice-contact deposits.

The North Branch watershed is dominated by forested land. The sub-dominant watershed land cover for the assessment reaches include urban, crop land and field. Except for one reach, orthophotos from the 1970s show that the North Branch was dominated by forest land. Downtown Wilmington has not changed much since the late 1800s. Many of the existing buildings were there at that time. The surrounding area, which now is reforested, was mostly logged during the late 1800s. The tourist industry in Dover began as early as 1900s where summer residences were developed on Handle Road and Cooper Hill. A later development boom occurred as a result of the construction of Mount Snow Ski Area in 1954. Lodges, motels, and restaurants sprang up after the ski area was developed as well as vacation homes (Town of Dover, 2005). Haystack Mountain Ski Area was founded in 1964. Chimney Hill, a development of vacation homes in the vicinity of Haystack, was constructed during 1974 and 1975. New development within the watershed continues today.

1.2.2 Flood History

Personnel in the Towns of Dover and Wilmington were contacted for information regarding the flood history of the North Branch River. According to Susan Haghwout (2005), Wilmington Town Clerk, there were several floods that have impacted the downtown area of Wilmington. One major flood occurred in 1938, which brought the water level five feet up the side of the town building at the intersection of Route 9 and Route 100. The Wilmington town clerk could recall another flood that occurred around 1976 where the basements of downtown businesses were damaged from floodwaters, a bridge was washed out, and that the water came up to the bottom of the Route 9 bridge. Ms. Haghwout also mentioned that a major culvert was washed out around this time on Cold Brook. According to Lana Palumbo (2005), Administrator for the Town of Wilmington, FEMA records show that there has also been some localized flooding from storm events that occurred in 1996 and 2000.

There have been no serious flood events in Dover that have caused major damage to structures. However, the Town Clerk of Dover did indicate that there were two storm events that caused some road washouts including a bridge along Blue Brook. These storm events occurred in 1973 and 1976 (Raymo, 2005).

Since there are no USGS stream gages within the North Branch watershed, data from another river was used to better understand the hydrologic history of the North Branch. Long term data from the U.S. Department of the Interior, U.S. Geological Survey (USGS) gage on the Walloomsac River near North Bennington, VT (gage #01334000) was obtained. The Walloomsac River gage was selected because it is located in the southern region of Vermont like the North Branch. Although the drainage area at the Walloomsac River gage is much larger (111 sq. miles) than the North Branch watershed, it does provide some useful information about when large flood events occurred. This gage has a continuous flow record from 1932 to the present. The long term record shows that there have been four events where peak discharges were between the ten year and 25 year recurrence interval. This occurred during water years[2] 1950, 1973, 1977 and 1987. Streamflows exceeded the 25 year recurrence interval in water year 1949 and the 50 year discharge in 1938 (Figure 4).

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

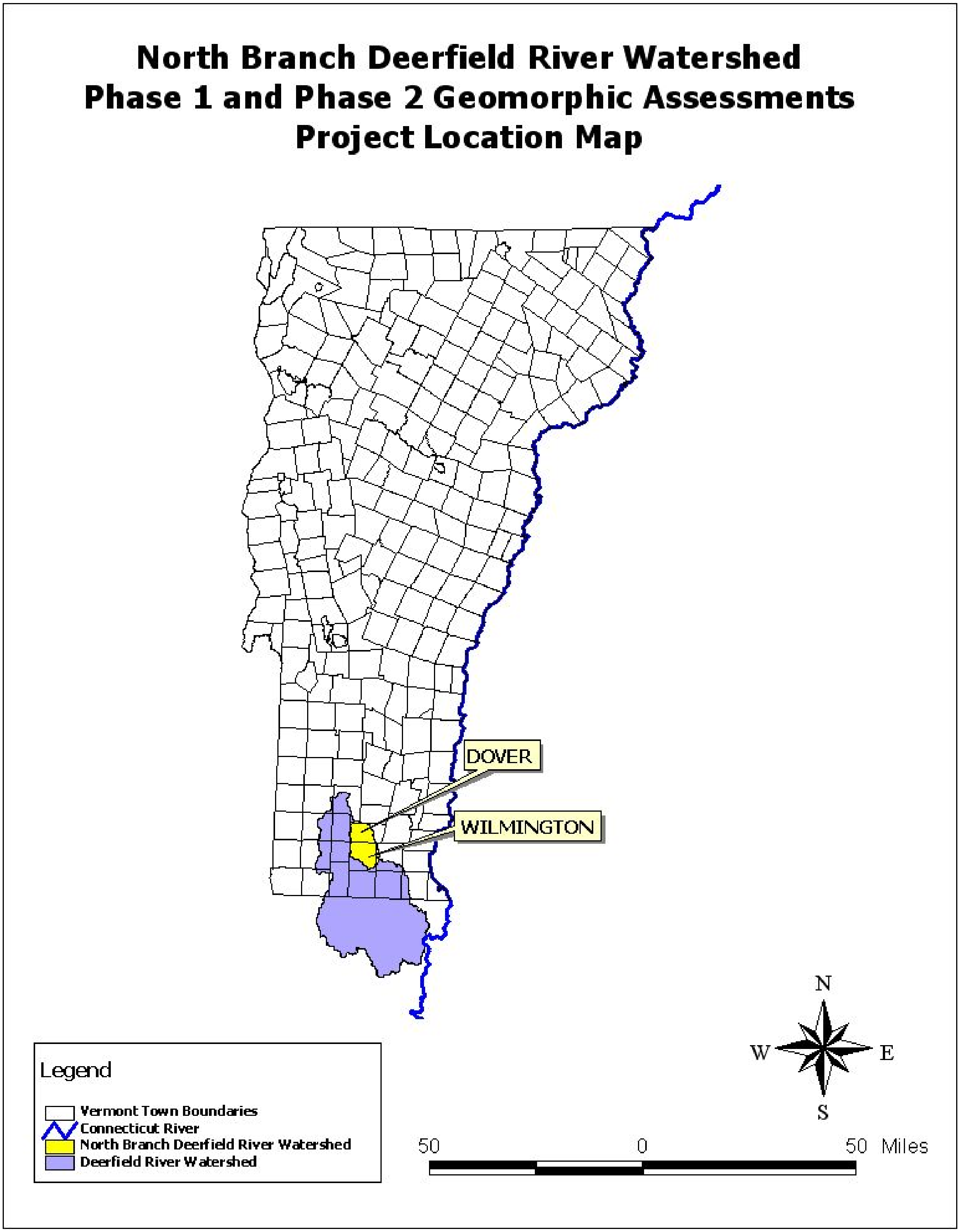

Figure 1. Project Location Map for the Phase 1 and Phase 2 Assessments

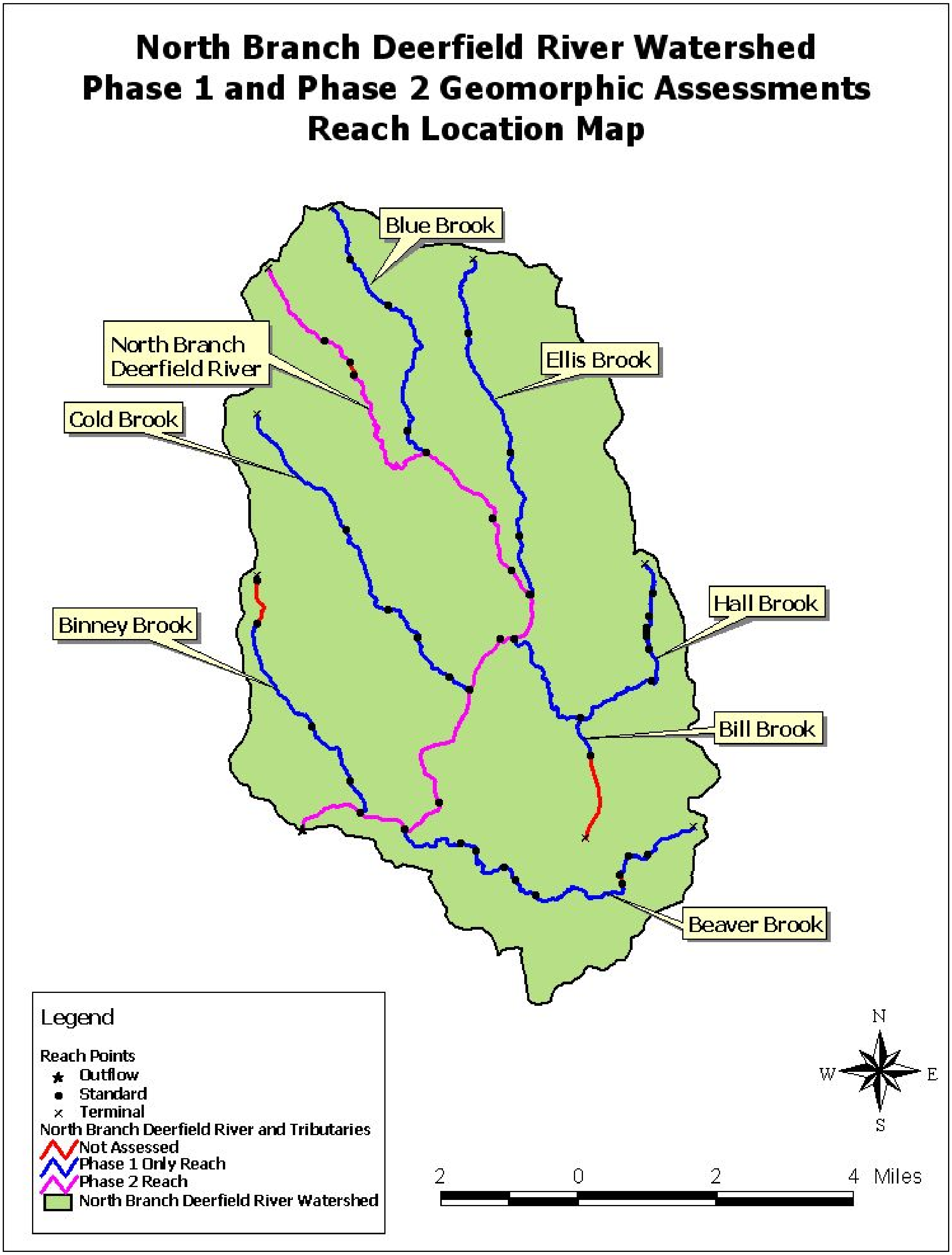

Figure 2. Reach Location Map for the Phase I and Phase 2 Stream Geomorphic Assessments

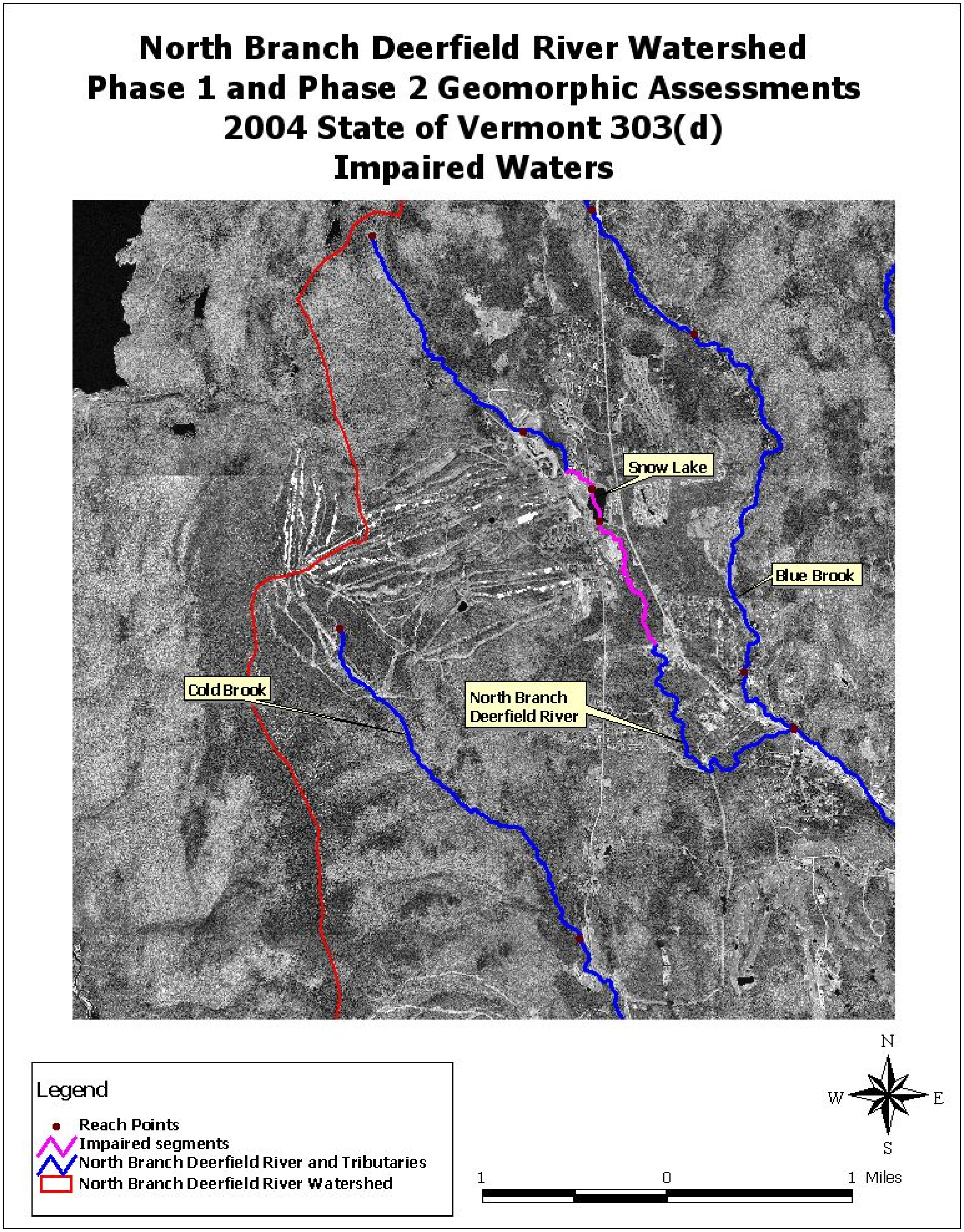

Figure 3. Impaired Segments of North Branch River

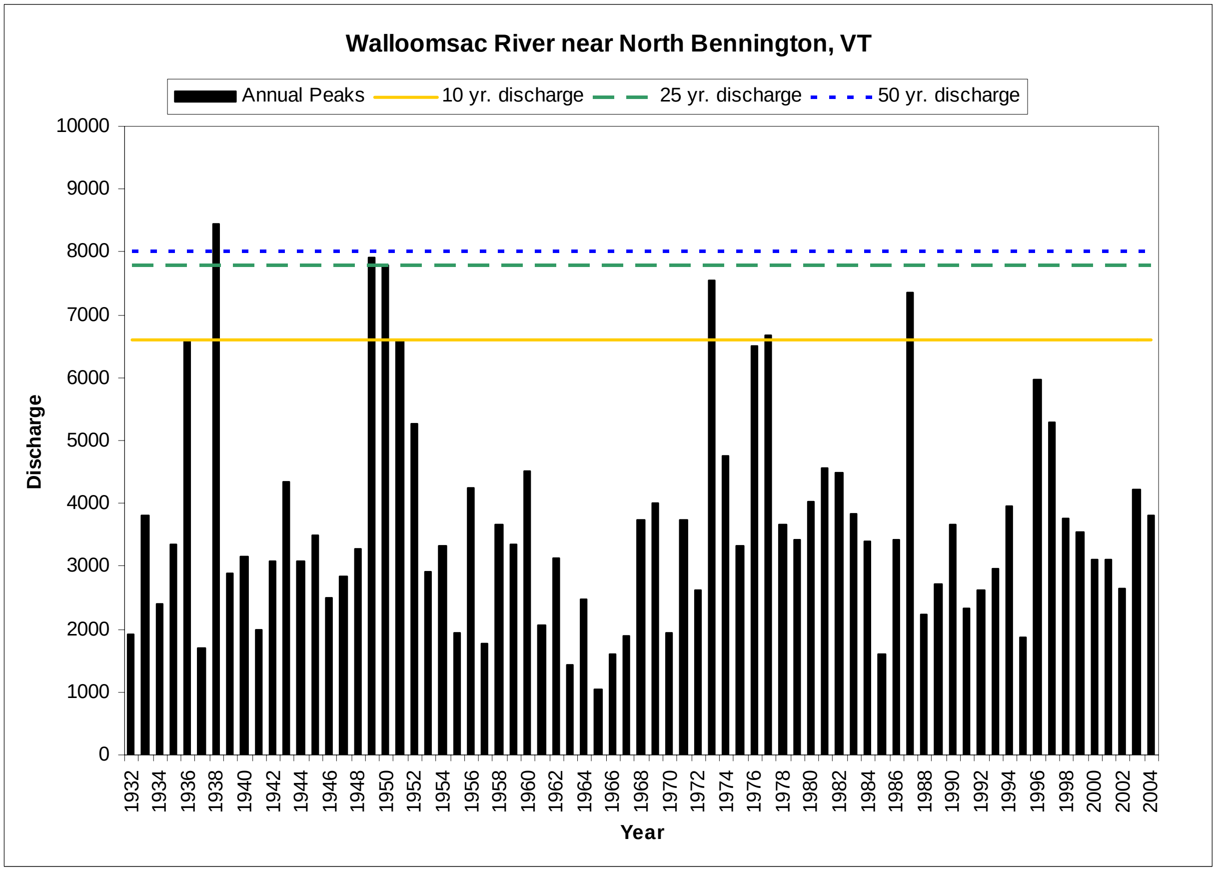

Figure 4. Flood Frequency Chart for Walloomsac River near North Bennington, VT

1.2.3 Channel Management History

Fred Nicholson, stream alteration engineer with the Vermont Agency of Natural Resources, was contacted to determine any channel management procedures that may have occurred in the watershed. He indicated that there was some historic dredging and straightening on the main stem where the river flows through downtown Wilmington. Mr. Nicholson also mentioned that in general anywhere there are agricultural fields near the river, the channel was straightened between 1973 and 1976 after the last statewide high water. This occurred mostly on the main stem of the river, but Ellis Brook near the golf course was also channelized. According to Mr. Nicholson, gravel mining is conducted on Cold Brook about one mile up from the confluence with the North Branch. Mr. Nicholson also mentioned that the banks were armored with rip-rap on the North Branch from the Route 100 Bridge in Wilmington to the confluence with the Deerfield River (Nicholson, 2005).

SECTION 2: PHASE 1 STREAM GEOMORPHIC ASSESSMENT

2.1 PHASE 1 METHODOLOGY

The Phase I assessment followed procedures specified in the Vermont Stream Geomorphic Assessment Handbook Phase 1 (Vermont Agency of Natural Resources 2005), and used version 3.02 of the Stream Geomorphic Assessment Tool (SGAT) GIS extension. All assessment data were recorded on the Agency of Natural Resources (ANR) Phase I data sheets, and were entered into the DMS.

2.1.1 Parameters

During the Phase 1 Assessment, data was collected for each parameter in Table 1. The parameters were then rated according to the following menu options (NS – not significant, low impact, high impact or No info –no information). A zero was scored for options NS and No info, a one for low impact and a two for high impact.

The reach indexing tool (RIT) was used to document steps 5.3, 5.4, and 6.1. This tool is an extension of ArcView and utilizes the Vermont Hydrography Dataset (VHD) (VCGI, 2003) to automate measuring the length of stream segments. The impacts were entered into an attribute table, which was uploaded to the DMS.

Table 1. 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

Table 1. Parameters included in Impact Scores	
Step #	**Parameter**
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
6.6	Wavelength Ratio
7.2	Bank Erosion – Relative Magnitude
7.3	Ice and Debris Jam Potential

2.1.2 QA Review

To assure a high level of confidence in the Phase 1 and 2 SGA data, strict QA/QC procedures were followed by BCE. These procedures involved a thorough in-house review of all data as well as automated and manual QC checks with the DEC River Management Program. The three base shapefiles (valley walls, meander centerlines, and subwatershed) were submitted to both Shannon Hill and Staci Pomeroy for QA review prior to running the SGAT extension. After Step 2 of the Phase 1 Assessment was completed, Bear Creek Environmental conducted its own manual QA review of the reference stream types. Then the SGAT project and resultant shapefiles were sent to the River Management Program for another QA review, which included a manual QA review of reference stream types. In July 2005, Phase 1 ArcView shapefiles were submitted to Shannon Hill for a QA review following the completion of Step 7 of the Phase 1 assessment.

BCE completed its own in-house QA review after all the Phase 2 data were entered into the DMS and the Phase 1 data were updated. Lengths of armoring, berms, and erosion on field forms were checked against DMS values as well as calculated lengths in GIS shapefiles. Then the Phase 2 GIS shapefiles were submitted to the ANR for a third QA review. Some minor revisions were made by Bear Creek Environmental to the DMS following this review.

2.2 PHASE 1 RESULTS

2.2.1 Reach Locations

The North Branch watershed was divided into 53 reaches for the Phase I Assessment. Pages 1 and 2 of Appendix A provide the reach locations including reach description, town where the reach is located, and latitude and longitude generated from SGAT. Five reaches were excluded from the assessment due to impoundments. Figure 2 shows the location of study reach used in the Phase 1 Assessment. Each point represents the downstream end of the reach.

2.2.2 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 valley confinement, and slope determined through remote sensing were used to determine the 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 (1996) classification systems.

Pages 3 and 4 of Appendix A provide a complete listing of reference stream types for each reach within the project area. The reference stream types, based on the Phase 1 Geomorphic Assessment are shown in Figure 5. The majority of the stream reaches fall within the "C" stream type (see Table 2). The riffle-pool type streams in this category accounted for approximately 44 percent of the length of assessed reaches, while the plane bed reaches accounted for three percent of the study area by length. These streams are narrow to very broad, have gentle to moderate slopes, and have cobble, gravel, or sand as the dominant bed material. A few of the reaches in the upper part of the watershed were not easily accessible and were not visited during the windshield survey. Best professional judgment was used to assign a bed form (e.g. step-pool, plane bed) to these reaches.

Fourteen of the 48 reaches (approximately 32 percent of the study area by stream length) fall within the “B” stream type. Twenty four percent of assessed reaches, by length, had plane bed bedforms while 4 percent were riffle-pool and four percent were step-pool systems. These B streams range from narrowly confined to broad, have steep to gentle slopes, and gravel or cobble bed material.

Eight reaches were categorized as “A” type streams. The cascade stream reaches comprise approximately 7 percent of the study area, by length, and the step-pool stream reaches comprise 11 percent of the study area. These streams are narrowly confined, have steep to very steep slopes and boulder or cobble as the dominant bed material.

Two reaches (3 percent of the study area) were classified as an “E” type stream. Both reaches are riffle-pool streams and have gentle slopes. The dominant bed material in these reaches is gravel.

Table 2. Reference Stream Type

Stream Type	Confinement	Channel Slope	Bed Material	Percentage by channel length of Assessed Reaches
A/ Cascade	Narrowly Confined	Very steep	Boulder	7
A/Step-Pool	Narrowly Confined	Very steep to steep	Cobble	11
B/Step-pool	Narrowly Confined to Narrow	Steep to moderate	Cobble	4
B/Riffle-pool	Narrowly Confined	Moderate	Gravel	4
B/ Plane Bed	Narrowly Confined, Semi-confined, Narrow or Broad	Moderate to gentle	Cobble-Gravel	24

Table 2. Reference Stream Type

Stream Type	Confinement	Channel Slope	Bed Material	Percentage by channel length of Assessed Reaches
C/Riffle-pool	Narrow, Broad or Very Broad	Moderate to gentle	Cobble, Gravel or Sand	44
C/Plane Bed	Very Broad	Moderate	Cobble-Gravel	3
E/Riffle-pool	Very Broad	Gentle	Gravel	3

2.2.3 Basin Geology and Soils

The characteristics of the North Branch watershed were determined using a combination of soils data, review of topographic maps, and information acquired during the windshield survey. Pages 5 and 6 of Appendix A provide a summary of the basin characteristics, such as alluvial fans, grade control structures, geologic materials, valley side slopes, and soil characteristics.

No alluvial fans were identified within the study reaches. Grade control structures such as ledge and dams were noted during the windshield survey. Channel spanning ledge was noted in three of the 48 reaches (T2.08, T2.09 and T2.13). Ledge acts as a grade control by keeping the base elevation of a river from being lowered, and prevents the river from incising in that location.

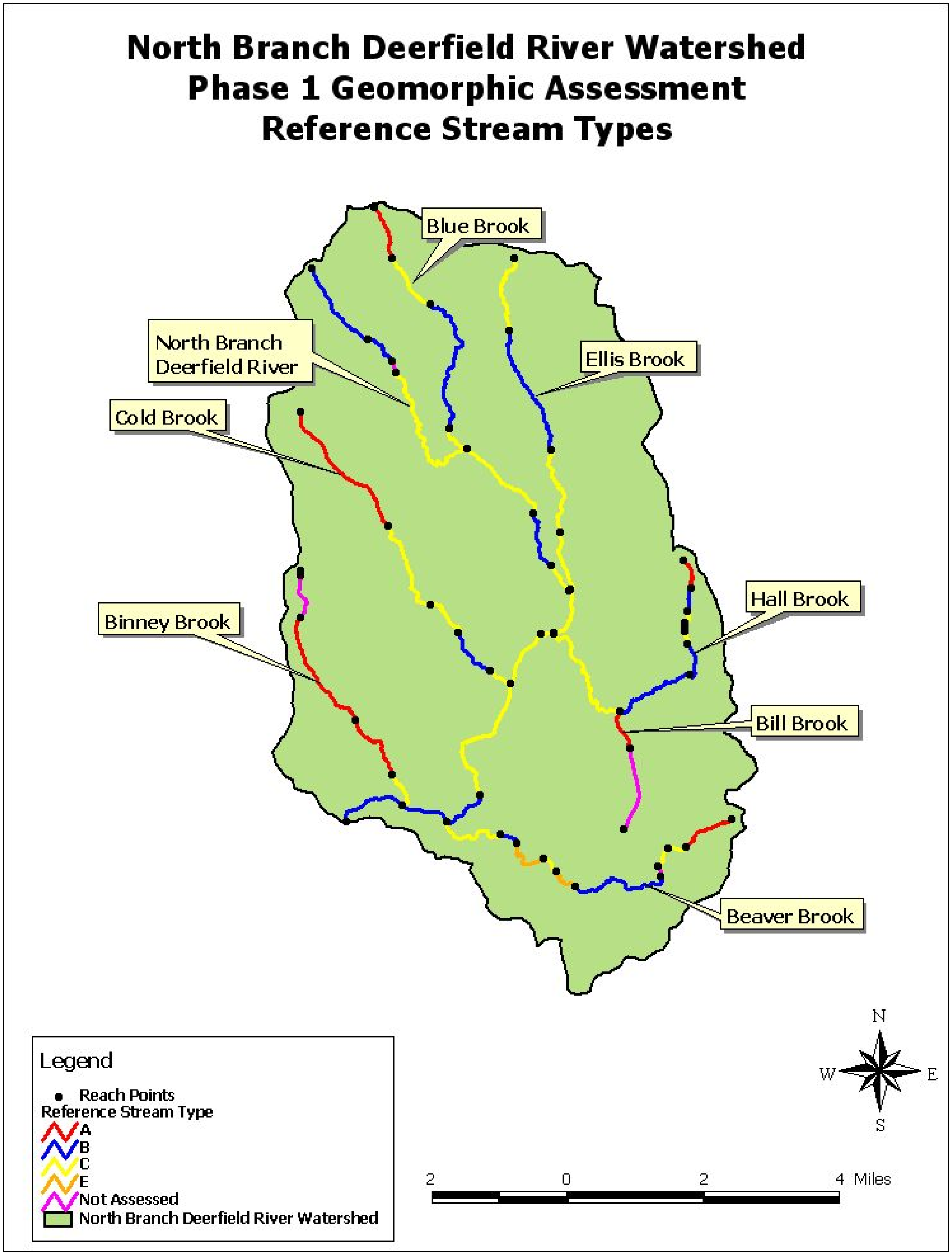

Figure 5. Stream Typing for Phase I Assessment Reaches

Six dams were noted within the study area. The largest dam is at Snow Lake and is located at the upstream end of reach T2.11 on the main stem. The other dams include Haystack Pond at the upper end of T2.01-S1.03, Lake Raponda at the upstream end of T2.06-S1.02 and two impounded man made ponds on reaches T2.02-S1.06 and T2.06-S1.01-S1.04. There is also a grade control weir on T2.10-S1.03 that was classified as a dam for the Phase 1 assessment. This weir appeared to be a temporary structure. Other types of grade controls were found on three reaches.

The steepness of the valley side slopes was determined using a combination of a topographic map and the soils layer. The valley side slope steepness was variable, but overall steep to extremely steep side slopes dominated the watershed with the exception of Hall Brook where there are some hilly and flat sections.

The soils information for the North Branch watershed is summarized on pages 7 through 10 of Appendix A. In general, the dominant surficial geology of the watershed consists of alluvium, glacial till and ice-contact deposits. The reaches characterized as "C" channels within the North Branch watershed have ice-contact deposits, alluvium, till, or "other" as the dominant geologic material. With few exceptions, the alluvial soils are flooded frequently and have slight to moderate erodibility. T2.07-S1.01 and T2.05, "C" type streams, had a dominant soil type of alluvium that is rarely flooded with moderate to severe erodibility. The rest of the "C" type reaches, which have till, ice-contact deposits or "other" as the dominant geologic materials, are rarely flooded and have moderate to very severe erodibility. The two reaches characterized as "E" channels have alluvial soils as their dominant geologic material. These soils are frequently flooded and have slight erodibility.

All dominant soils in reaches characterized as A or B streams were till or ice-contact deposits. These soils are rarely flooded and have very severe erodibility.

2.2.4 Land Cover – Reach Hydrology

The land use within the watershed plays a role in the hydrology of the receiving waters. The percentage of urban and cropland development within the watershed are factors which change a watershed's response to precipitation. The most common effects of urban and cropland development is increasing peak discharges and runoff by reducing infiltration and travel time (United States Department of Agriculture 1986). The land use/land cover within the stream corridor itself is also an important parameter to evaluate. The land use/land cover plays an important role in the sediment deposition and erosion which occurs during annual flood events (Vermont Agency of Natural Resources 2005a).

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 follow:

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

As provided on pages 11 and 12 of Appendix A, the dominant watershed land cover/land use within the North Branch watershed is, in general, forest. The lowest two reaches on Binney Brook resulted in a watershed /land use impact rating of high, while the remaining reaches within the watershed received an impact rating of either low or not significant.

The dominant land cover/land use within the river corridor, also summarized on pages 11 and 12 of Appendix A, was forested land for all but six reaches. These six reaches had urban land or field as their dominant land use. The impact rating for land use in the river corridor was high for 26 of the reaches, which is about 54 percent of the total number of reaches. The remaining reaches had an impact rating of either low or not significant.

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. Stream reaches, which lack a high quality riparian buffer, are at significantly higher risk of experiencing high rates of lateral erosion. An impact rating of high is assigned when over 75% of the reach has little or no buffer (0-25 ft) on either bank. None of the assessment reaches received a high impact rating for riparian buffer condition, although five of the reaches had 50 percent or more of the reach with little or no buffer on one or more banks. As summarized on pages 13 and 14 of Appendix A, approximately half of the reaches had between 25 and 75 % of the reach with little and no buffer, and were subsequently assigned an impact rating of low. On the main stem of the North Branch, 8 of the 13 reaches assessed had dominant riparian buffer widths of 0 to 25 feet along at least one of the banks. This documents the poor riparian buffer quality of much of the mainstem of the North Branch.

2.2.5 Historic Channel Modifications

Channel modifications may impact a stream reach by affecting the hydraulics and the sediment regime. Historic channel modifications were assessed in this Phase I study by evaluating flow regulations, bridges and culverts 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 15 and 16 of Appendix A.

Flow Regulations

Brian Fitzgerald, with the Dam Safety Section of the Vermont Agency of Natural Resources, was contacted for information regarding flow regulation within the North Branch watershed. He indicated that there are two locations where there is water removal for the purposes of snowmaking: Snow Lake and Cold Brook. Both reaches with water withdrawals for snowmaking were assigned a high impact for flow regulation.

Reach T2.11 is on the main stem of the river and is impacted by the water withdrawal from Snow Lake and the onstream pond just upstream of this reach. The drainage area at Snow Lake is 2.64 mi^2. The maximum capacity for the withdrawal is 4,000 gpm with a minimum flow requirement of 0.15 cfs/mi^2. The other water withdrawal for snowmaking occurs within reach T2.04-S1.04 on Cold Brook near Haystack Ski Area. The drainage area here is 3.35 mi^2 and the minimum flow requirement is 0.58 cfs/mi^2 (Fitzgerald, 2005).

Five more reaches were found to have impoundments, which regulate the flow of the river. Three of these reaches had an impact rating of high and one an impact rating of low. The fifth reach, T2.01-S1.03, could not be accessed so the impact from the impounded pond just upstream of this reach, Haystack Pond, is unknown.

Two reaches were impacted by the dam on the Deerfield River constructed to create Harriman Reservoir. Water from the reservoir backs up into reaches T2.01 and T2.02 and therefore has changed the natural flows and channel geometry. An impact rating of high was assigned for these two reaches for flow regulation.

Bridges and Culverts

As part of the Phase 1 Stream Geomorphic Assessment, the number of bridges and culverts within the study reach were counted by identifying stream crossings on the topographic map and orthophotos. These stream crossings were confirmed during the windshield survey and Phase 2 Assessment. The percentage of the reach impacted by stream crossing structures was estimated during the windshield survey and from orthophotos. 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. The impact from bridge and culverts on stream dimension, pattern or profile was low for 31 of the 48 reaches. The remaining reaches appeared to be not significant and no reaches were rated as high impact.

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, 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. Stream alteration permits can typically be used to identify bank revetments within a watershed of interest.

Rock riprap and stone walls were the only types of revetments noted within the study area. 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	No data sources are available to determine if the bank armoring exists
Not Evaluated	All data sources (as described by the meta data) have not been evaluated.

Bank armoring was noted in 12 of the 48 reaches. Armoring received an impact rating of high for 3 of the reaches, T2.03, T2.09 and T2.10, and low or not significant for the remaining reaches that were evaluated.

Channel Straightening

Initial evidence of historic channelization projects were recorded from interviews with Fred Nicholson, stream alteration engineer with the Vermont Agency of Natural Resources. Orthophotos were also reviewed to identify channelized stream sections, which were then confirmed during the windshield survey and Phase 2 Assessments. The total reach length (in feet) and the percentage of the reach length directly impacted by the channel modification were noted. Categories considered as part of the Step 5.4 (Channel Straightening) 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 a part of the straightening of the river.
- None – No known channel straightening.
- No Data – No data sources are available to determine if the channel has been straightened.
- Not Evaluated – All data sources (as described by the meta data) have not been evaluated.

.

The only channel modification noted within the North Branch watershed was straightening. Portions of stream reaches that have been historically channelized or straightened are identified below in Figure 6. Channel straightening was identified in 25 of the 48 reaches. Twenty of these reaches were given an impact rating of high for channel straightening, while 5 had an impact rating of low.

Dredging History

Fred Nicholson, stream alteration engineer with the Vermont Agency of Natural Resources, was contacted for information regarding the dredging of the North Branch. He indicated that historically dredging occurred on the main stem where the river flows through the Town of Wilmington. Therefore, reaches T2.02 and T2.03 were impacted by dredging and given a rating of high. Mr. Nicholson also mentioned that there is a commercial gravel pit along Cold Brook about 1 mile upstream from the confluence with the North Branch on reach T2.04-S1.02. He said that gravel is taken out of the stream from time to time to supply this gravel pit (Nicholson, 2005). This reach was given an impact rating of high. During the Phase 2 Assessment, dredging was noted in T2.01 and T2.10. This information was used to update Phase 1 data, and these reaches were given an impact rating of high. No data were available for the remaining reaches.

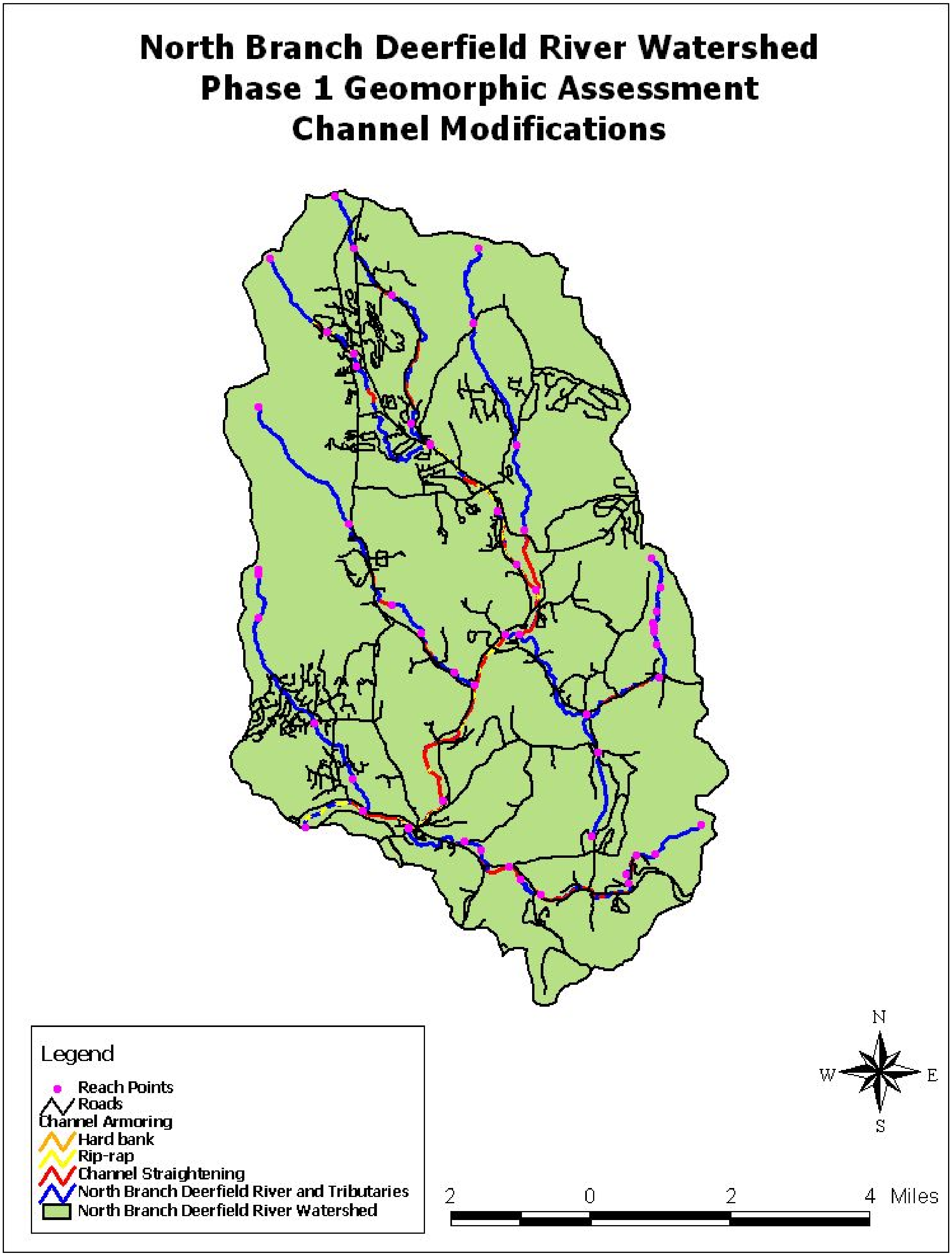

Figure 6. Instream Channel Modifications Identified for Phase I Reaches

2.2.6 Floodplain Modifications

In this step of the Phase I assessment, careful attention is paid to infrastructure and other development which restricts 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. Some of the primary factors, which may influence floodplain function in the North Branch, are discussed below: pages 17 and 18 of Appendix A contain the Phase 1 information for Floodplain and Planform changes.

Berms and Roads

Using information from maps, orthophotos, and the windshield survey, the percentage of the river corridor length along which berms, roads, railroad, or improved paths run parallel to the stream was estimated. Reaches where berms, roads, railroads or improved paths were located along 20 percent or more of the river corridor were given impacted ratings of high. Thirty-two of the 48 reaches contained berms and/or roads within the river corridor. Nine of the 13 reaches on the main stem of the North Branch received an impact rating of high for berms and roads. In addition, thirteen of the tributary reaches were given an impact rating of high for berms and roads. The remaining reaches had an impact rating of low or not significant.

River Corridor Development

The river corridor development parameter looks at whether developments within the river corridor are effectively decreasing the belt width. The percentage of the reach length with houses, fill, parking lots or other development within the river corridor was tabulated using maps, orthophotos, and knowledge from the windshield survey. Twelve of the 48 reaches had an impact rating of high for river corridor development. The remaining reaches were either rated low or not significant.

Depositional Features

The 1990s orthophotos series (1:5000) as well as results from the windshield survey were used to evaluate depositional features within the North Branch watershed. The presence of bars (mid channel or point bars) and deltas were noted in each of the study reaches. The ANR 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.

Seven of the 48 reaches had multiple depositional features present. All of these reaches were on the main stem: T2.03, T2.04, T2.07, T2.09, T2.10, T2.11 and T2.14. Point bars were observed on 12 reaches and mid-channel bars were observed on 3 reaches. In eight of the 48 reaches, the impact was rated as high. The remaining reaches were low or not significant.

Meander Migration

Orthophotos were used to evaluate areas where the North Branch and its tributaries have migrated, bifurcated, or avulsed[3]. Current orthophotos from 1994 and historic orthophotos from 1974 and 1975 were overlaid to compare the location of the river channel over time. The current and the historic orthophotos span a range of approximately 20 years. Eight reaches in the study area received an impact rating of high for meander migration, while 14 reaches received an impact rating of low. One of the reaches with a low impact rating was due to a channel avulsion.

Meander Width and Wavelength

The 1990 series (1:5000) orthophotos in conjunction with topographic maps were used to determine the meander belt width and the meander wavelength for streams typed in

[3] An avulsion is a change in planform resulting from a meander cut-off.

Step 2.11 as "C" or "E" riffle-pool or ripple dune reference stream types. 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.

The meander belt width is the horizontal distance between to 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. The ANR Phase I protocol considers 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. Nineteen of the 25 evaluated reaches fell outside of the range expected for channels which are in regime. Twelve of the study reaches were rated as high impact for meander width ratio, and the rest received an impact rating of low or not significant.

All but two of the stream reaches which resulted in a low or high impact rating had meander width ratios of less than 5. These low values may indicate the stream has become straighter and steeper, possibly resulting in degradation and loss of access to its floodplain. Field observations confirm the finding that the North Branch has lost access to its floodplain in many locations, especially along roads.

The meander wavelength consists of two bendways. The wavelength ratio is calculated by dividing the average wavelength by the bankfull channel width. Leopold 1994 and Williams 1985 (cited in Vermont Agency of Natural Resources, 2005a) have shown unconfined, gravel dominated streams in shallow-sloped valleys to have wavelengths in the range of 10 to 12 times the channel width. Sixteen of the reaches resulted in a high impact rating for meander wavelength while five reaches received an impact rating of low.

2.2.7 Bed and Bank Windshield Survey

The dominant bed form, dominant bank material, bank erosion/bank height, and debris/ ice jam potential were recorded during the windshield survey, and these results are summarized on pages 19 and 20 of Appendix A. The dominant bed form and dominant bank material were previously discussed under Section 4.2, Stream Typing. 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. Bank erosion was rated as high for two reaches and low or not significant for the rest of the reaches. The bank erosion impact ratings are mapped in Figure 7.

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. Four reaches received an impact rating of high for debris/ice-jam potential. Thirteen reaches received an impact rating of low for debris/ice jam potential.

2.3 PHASE 1 DATA ANALYSIS

2.3.1 Phase 1 Impact Scores

The Phase 1 evaluates parameters that may cause channel adjustment. These parameters are grouped into four major categories: land use, instream modifications, floodplain modifications, and bed and bank windshield survey. For each parameter, the maximum impact score for the entire watershed is 96 (48 reaches times impact score of 2). As shown below in Figure 8, the corridor land use parameters in the land use category received the highest impact rating for the watershed. The parameters watershed land use, berms and roads, riparian corridor development, channel modifications and average wavelength also resulted in high scores.

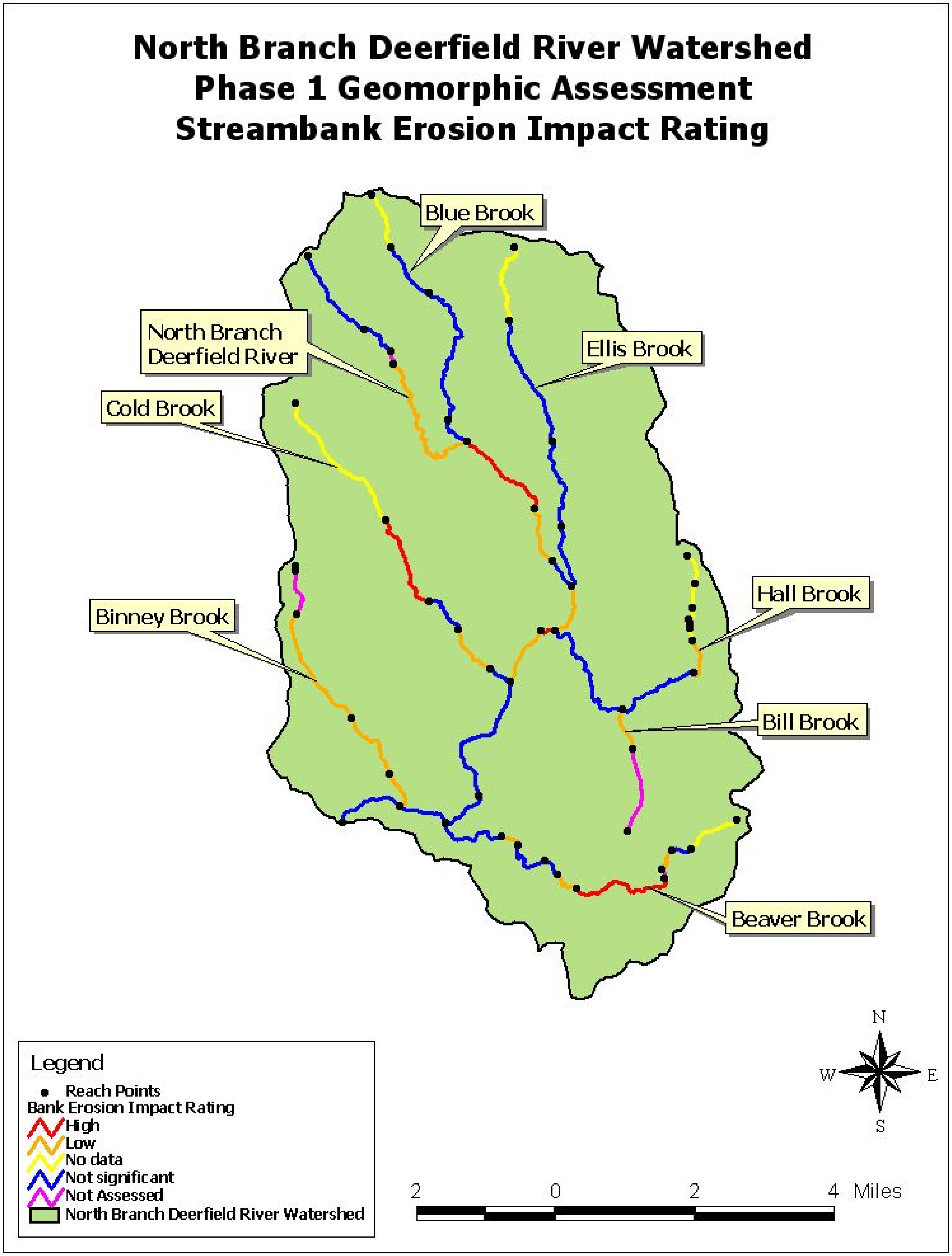

Figure 7. Streambank Erosion Impact Rating for North Branch River Watershed

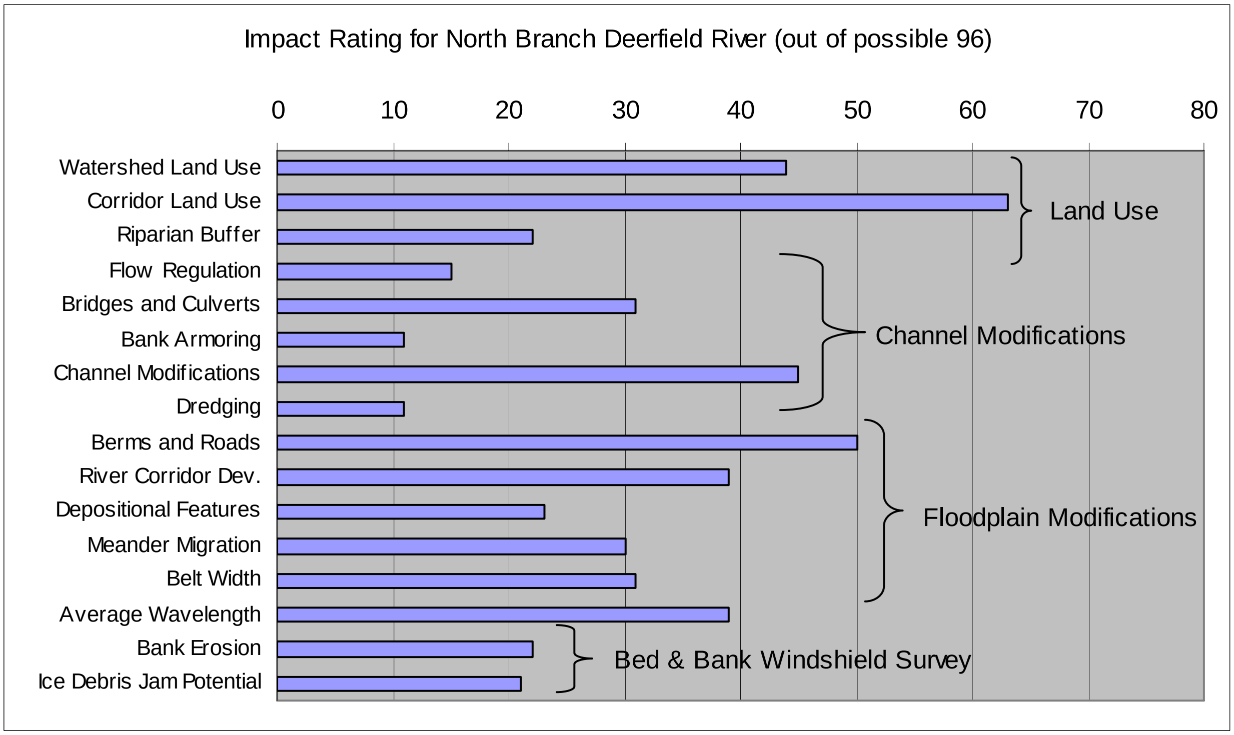

Figure 8. Impact Rating for North Branch Watershed by Parameter and Category

The total impact scores for the Phase I assessment are provided on pages 21 and 22 of Appendix A. The reach conditions from the Phase 1 database are mapped below in Figure 9 and shown in Table 3.

Based on impact ratings, there were two reaches in poor condition: T2.04-S1.04 (Cold Brook) and T2.10 (main stem of North Branch). T2.10 has undergone significant 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. Reach T2.04-S1.04 has undergone significant floodplain modifications and some channel modifications. It may also be impacted by the snowmaking water withdrawals.

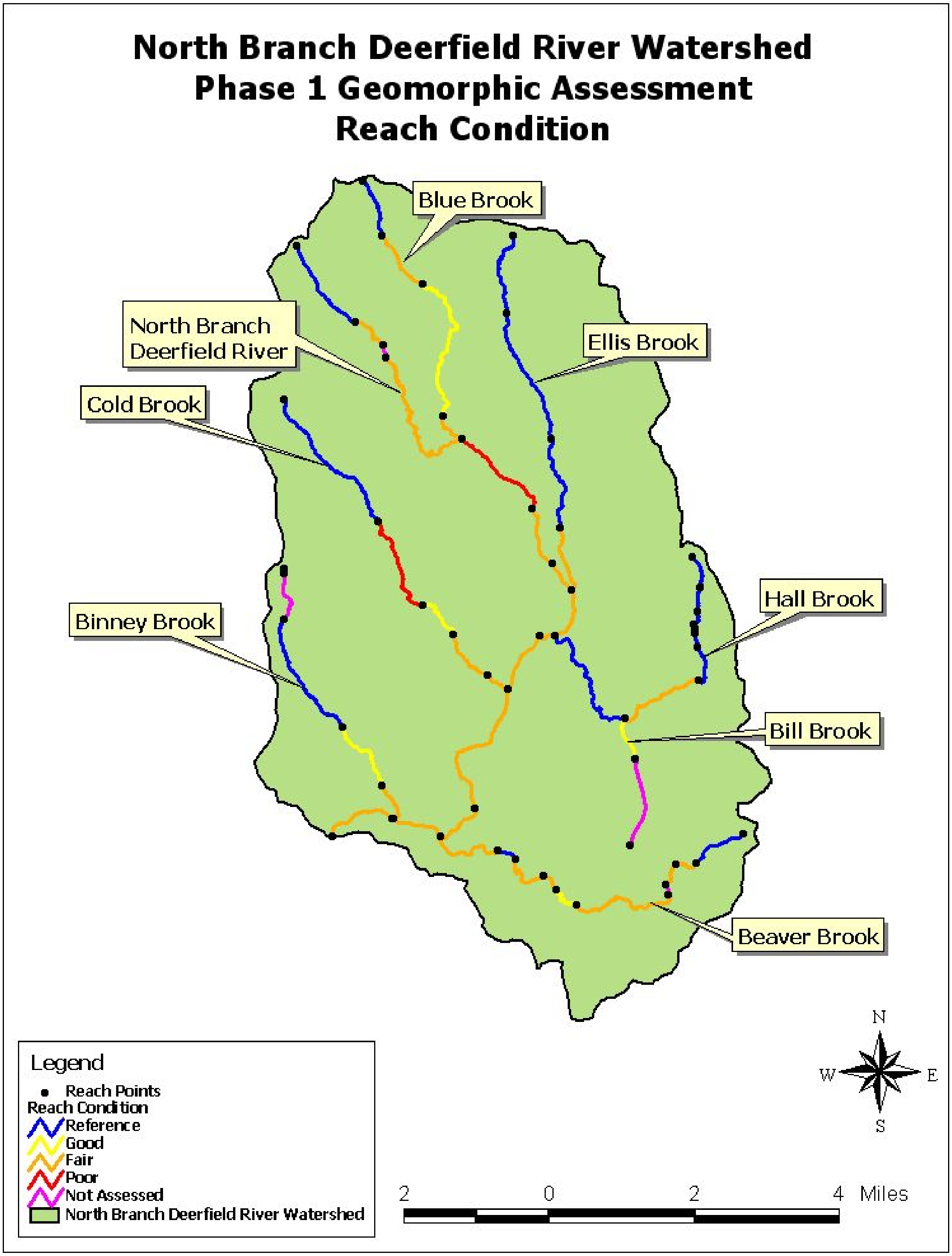

Figure 9. North Branch River Watershed Phase I Reach Condition

Table 3. Reach Assessment

Reach Number	Confinement	Total Impact Score	Watershed Size (square miles)	Within Watershed Condition (from Phase I Database)
T2.01	NC[4]	12	55.87	Fair
T2.01-S1.01	VB[5]	11	3.68	Fair
T2.01-S1.02	NC	5	3.18	Good
T2.01-S1.03	NC	5	0.88	Reference
T2.01-S1.05	NC	0	0.02	Reference
T2.02	SC[6]	15	50.68	Fair
T2.02-S1.01	VB	16	8.26	Fair
T2.02-S1.02	SC	6	7.58	Reference
T2.02-S1.03	VB	12	7.01	Fair
T2.02-S1.04	VB	14	6.22	Fair
T2.02-S1.05	VB	13	6.17	Good
T2.02-S1.06	NC	15	2.97	Fair
T2.02-S1.08	VB	15	1.48	Fair
T2.02-S1.09	VB	11	1.26	Fair
T2.02-S1.10	NC	0	0.53	Reference
T2.03	NC	18	41.64	Fair
T2.04	VB	20	41.35	Fair
T2.04-S1.01	BD[7]	9	8.43	Fair
T2.04-S1.02	SC	13	8.10	Fair
T2.04-S1.03	VB	9	7.26	Good
T2.04-S1.04	BD	21	4.81	Poor
T2.04-S1.05	NC	1	2.18	Reference
T2.05	NW[8]	17	29.87	Fair
T2.06	VB	14	28.59	Fair
T2.06-S1.01	VB	10	6.73	Reference

[4] Narrowly Confined
[5] Very Broad
[6] Semi-confined
[7] Broad
[8] Narrow

Table 3. Reach Assessment				
Reach Number	Confinement	Total Impact Score	Watershed Size (square miles)	Within Watershed Condition (from Phase I Database)
T2.06-S1.01-S1.01	SC	12	3.95	Fair
T2.06-S1.01-S1.02	SC	5	1.27	Reference
T2.06-S1.01-S1.03	NW	3	0.59	Reference
T2.06-S1.01-S1.04	NW	7	0.48	Good
T2.06-S1.01-S1.06	NW	3	0.41	Reference
T2.06-S1.01-S1.07	SC	1	0.32	Reference
T2.06-S1.01-S1.08	NC	0	0.19	Reference
T2.06-S1.02	NC	9	1.11	Good
T2.07	VB	19	21.77	Fair
T2.07-S1.01	VB	16	9.28	Fair
T2.07-S1.02	BD	4	7.03	Reference
T2.07-S1.03	NC	3	2.40	Reference
T2.07-S1.04	VB	1	0.97	Reference
T2.08	VB	17	10.92	Fair
T2.09	BD	13	10.80	Fair
T2.10	VB	22	10.26	Poor
T2.10-S1.01	VB	16	3.63	Fair
T2.10-S1.02	SC	11	3.41	Good
T2.10-S1.03	NW	12	1.48	Fair
T2.10-S1.04	NC	3	0.57	Reference
T2.11	VB	16	5.13	Fair
T2.13	NW	11	2.11	Fair
T2.14	NC	9	1.02	Reference

Streams in fair condition are fully in adjustment and are experiencing major and rapid changes due to recent floodplain and channel modifications, land cover changes, and/or loss of riparian buffer. Fifty percent of the reaches, both confined and unconfined, were in the fair category.

Six of the 48 reaches were placed in the good category based on the output from the Phase I database. The streams in the good category had experienced some degree of human-induced change to their watershed, floodplain and/or channel and appeared to be undergoing only minor adjustments. With one exception, the stream reaches in good condition were generally located in the middle of the watershed (i.e. not in the headwaters and not near the lower end).

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. Most streams in reference condition were found in the headwaters and were all A or B type streams (i.e. confined).

Total Impact scores on the main stem of the North Branch ranged from 9 to 22 as illustrated in Figure 10. The highest impacts were found on reaches T2.03 and T2.10 which run through the villages of Wilmington and West Dover. High impacts scores were also recorded on reach T2.04 and T2.07 which have both been extensively straightened and impacted by Route 100. BCE found no apparent trend in impact scores from upstream to downstream.

2.3.2 Phase 1 Adjustment Processes

Pages 23 and 24 of Appendix A provide a summary of the primary adjustment processes that were predicted based on the Phase 1 Stream Geomorphic Assessment. The Phase 1 data suggest that many of the stream reaches are experiencing more than one type of channel adjustment process. Reaches in poor condition appear to be degrading, aggrading and experiencing significant planform adjustment.

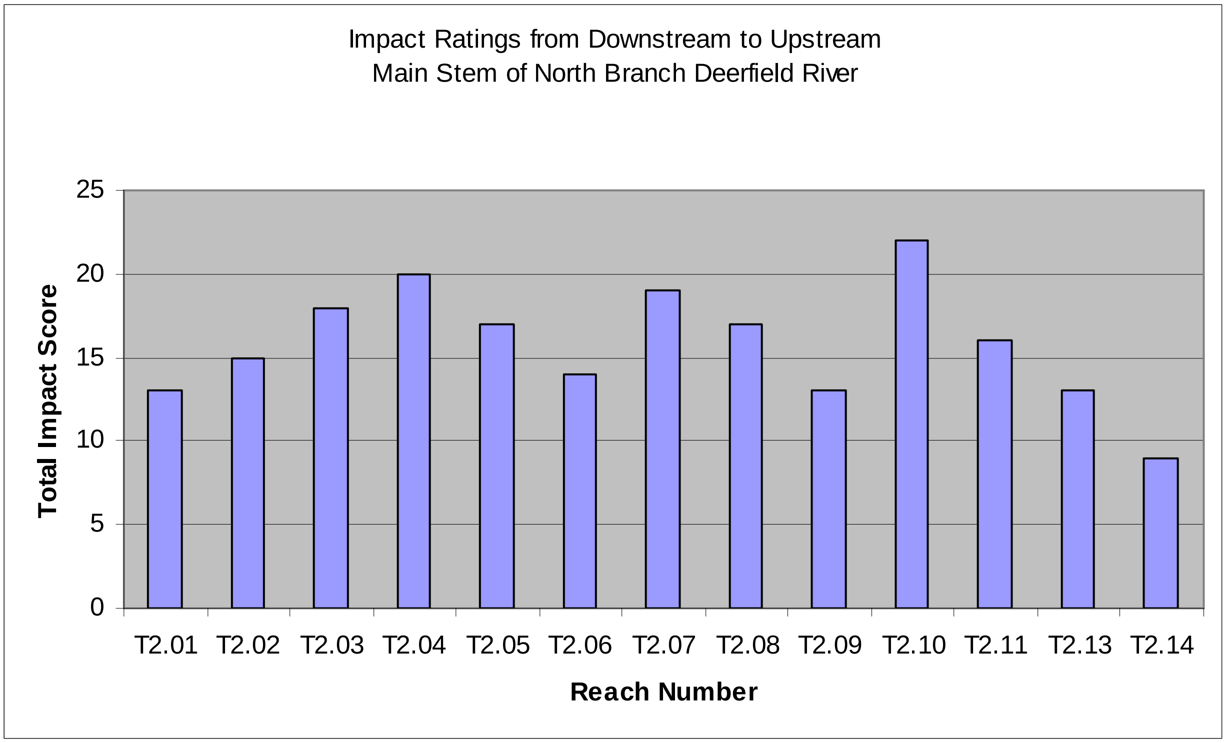

Figure 10. Impact Ratings from downstream to upstream on the main stem of North Branch

2.3.3 Phase 1 Reach Sensitivity

The stream sensitivity was 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. The reach sensitivity is summarized on pages 23 and 24 of Appendix A. Seventy-five percent of the reaches were evaluated for stream sensitivity. The bed material of 25 percent of the reaches could not be determined due to either the channel being too deep or the reach being inaccessible. Of the 36 reaches evaluated, 18 reaches resulted in a high sensitivity, while the rest had a moderate sensitivity.

SECTION 3: PHASE 2 STREAM GEOMORPHIC ASSESSMENT

3.1 PHASE 2 METHODOLOGY

The Phase 2 assessment followed procedures specified in the Vermont Stream Geomorphic Assessment Handbook Phase 2 (Vermont Agency of Natural Resources 2005b). All assessment data were recorded on the Agency of Natural Resources Phase 2 data sheets, and were entered into the ANR Stream Geomorphic Assessment data management system (DMS). The Phase 1 database was updated using the field data from the Phase 2 assessment.

3.1.1 Phase 2 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 2005b). 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.

3.1.2 Phase 2 QA/QC Review

The DMS and the ArcView Shapefiles for the North Branch Phase 2 study were submitted to Shannon Hill of the ANR for a quality assurance (QA/QC) review in December 2005. The Phase 1 DMS and ArcView shapefiles were updated by Michael Blazewicz and Pamela DeAndrea based on the Phase 2 field assessment work during the

Phase 2 QA/QC process in late September 2005. Mary Nealon and Michael Blazewicz provided QA/QC to critical components of the RGA data in December of 2005. Some minor revisions to the Phase 2 DMS were made in response to QA/QC comments received from Shannon Hill in January 2006.

3.2 PHASE 2 RESULTS

Phase 2 assessments of thirteen reaches were performed by BCE during July and August 2005. One reach in the mainstem, T2.12, was not assessed due to the Snow Lake impoundment. Reach T2.01 was heavily influenced by the Harriman Reservoir, and therefore, only partially assessed. Segment T2.11-B was heavily influenced by beaver dams, and therefore not fully assessed. Due to the remote location and intermittent flow regime, segment T2.14-D was not assessed. In total, the thirteen assessed reaches were broken into nineteen segments following the Phase 2 protocol (ANR 2005b). The Phase 2 Reach Summary Reports from the ANR Data Management System for each segment are provided on pages 1 through 42 of Appendix B.

3.2.1 Reach T2.01

The lowest reach on the North Branch studied by BCE scientists begins at the confluence with the Harriman Reservoir and continues upstream to the first major tributary, Binney Brook (T2.01-S1.01). This reach drains a watershed area of 55.87 square miles. Vermont Route 9 runs along the right corridor of this reach for almost its entire mile long length. Encroachment from the road has reduced the right buffer width in many areas to less than 25 feet wide. The road, and associated development, has also necessitated the rock armoring of 1275 feet of the right bank.

The most important influence on the geomorphic and habitat condition of this reach is the Harriman Reservoir. Store and release operations of the Harriman dam influence this reach significantly. As the lake levels rise, this reach becomes a lentic system (Figure 11). Due to the heavy influence of the damming, BCE scientists were unable to conduct a meaningful RGA and RHA assessment.

Figure 11: T2.01 is heavily influenced by the store and release damming of Harriman Reservoir. RGA and RHA data were not collected for this reach.

3.2.2 Reach T2.02

Reach T2.02 begins at the confluence of Binney Brook (T2.01-S1.01) and continues upstream to the confluence of another major tributary, Beaver Brook (T2.02-S1.01). The total reach length is slightly over 4000 feet. The right and left corridors of this reach has been highly impacted by Vermont Route 9, South Main Street, and Shafter Street. BCE scientists surveyed five stormwater inputs during the assessment of this reach. The riparian buffer has been removed on both sides to an average width of 0 to 25 feet.

The roads and associated development have altered the channel confinement of this reach from a semi-confined to a narrowly confined channel. As a result of this change in channel confinement, the reach has historically incised and widened. The Deerfield River at this reach has departed from its reference stream type of "B" and is now classified as a "F" channel. This reach is straighter and wider than it was in its reference condition (Figure 12).

Figure 12: T2.02 has become confined by roads. It has incised and widened into an "F" type plane bed channel.

3.2.3 Reach T2.03

During the Phase 2 Assessment, Reach T2.03 was broken into two segments by BCE scientists. The break was made to capture a change in channel confinement associated with an opening of the valley walls that resulted in a change in reference stream type within the reach.

Segment T2.03-A

Segment T2.03-A begins upstream of the confluence of Beaver Brook and runs through the village of Wilmington, Vermont. It is 2600 feet in length before the valley wall opens and segment T2.03-B begins. The river corridor of this segment has been highly altered by development. Vermont Route 100 and commercial development run along the entire left corridor while Ray Hill Road and village development heavily impact the right corridor. Over half of the left bank has been confined by rock armor and/or stone and cement walls (Figure 13).

By reference, segment T2.03-A is a "B" type channel. Due to historic floodplain encroachment, either the stream has degraded or the floodplain has been filled thereby effectively increasing the amount of incision through this segment. There is currently some minor aggradation, widening, and planform adjustment occurring, however, boundary conditions of the rock walls and some bedrock ledge are preventing further channel evolution from continuing. This segment has become a "F" type channel that has been locked into stage II of the F-stage evolution model (Appendix C).

Figure 13: Segment T2.03-A has been extensively channelized through Wilmington village. Historic degradation, widening, and floodplain fill have created a "F" type channel.

Segment T2.03-B

T2.03-B is a short segment of just over 1000 feet in length. Here, upstream of Wilmington village, the valley walls of the North Branch open up and the river becomes less entrenched. Development in the village gives way to hay fields as the land use in the valley becomes dominated by agricultural land. Throughout this reach the riparian buffer still only averages between 0 and 25 feet wide on both sides of the stream.

Although Vermont Route 100 runs through the entire left corridor of the stream channel, the channel is still unconfined (narrow) and has been classified as a "C" type channel dominated by gravel substrates (Figure 14). There is some evidence of incision through this reach (incision ratio is 1.35) as well as minor widening and planform adjustment. Currently, the major adjustment process occurring in this reach is aggradation.

Figure 14: Typical cross-section along segment T2.03-B with weak riffle-pool bedform. The river has shown minor degradation, widening, and planform adjustment. Currently there is major aggradation occurring within the reach.

3.2.4 Reach T2.04

Reach T2.04 was broken into two segments by BCE scientists, who observed a change in channel confinement associated with the encroachment of Route 100. The change in confinement has resulted in a departure from the reference stream type for segment T2.04-B.

Segment T2.04-A

North Branch segment T2.04-A extends for over a mile upstream of Wilmington Village. It ends where Route 100 pinches off the floodplain of the river causing a change in stream type. The predominant land use though the reach is agricultural. This reach has been extensively straightened and pushed up against the right valley wall. Historic straightening, and evidence of gravel extraction has led to some channel incision (incision ratio of 1.34) and widening. Currently there are signs of active channel aggradation and planform adjustment. The channel is attempting to narrow through bar development; however, some recent gravel extraction is maintaining an overwide channel as seen in Figure 15. Additionally, several active flood chutes and multiple diagonal bars indicate that the segment is attempting to regain the sinuosity that has been lost from historic straightening.

Figure 15: Bar development along T2.04-A indicates the channel is attempting to narrow and regain sinuosity. Gravel extraction, however, on this and other bars in the reach is maintaining an overwide channel.

T2.04-B

North Branch reach T2.04-B begins where Vermont Route 100 runs up against the right bank of the river 3700 feet downstream from the confluence of Cold Brook. The encroachment of Route 100 on the floodplain of the North Branch has changed the channel confinement from a very broad valley to a semi-confined valley. This change in channel confinement, along with an almost complete straightening of the channel within this segment, has changed the stream type from its reference "C" to a more confined "B" type channel. This extensive alteration has also affected the bedform of the stream (as well as the habitat). The bedform has likely changed from a riffle-pool to a plane bed form that now provides little depth cover for fish and aquatic organisms (Figure 16). Habitat and river health have also been affected by the removal of the riparian buffer on the right bank which now averages less than 5 feet wide from the top of the bank.

Figure 16: Segment T2.04-B has been extensively straightened and confined by Route 100. It is now a "B" type channel with a plane bed form.

3.2.5 Reach T2.05

North Branch reach T2.05 begins at the confluence with Cold Brook and flows through hay and residential lands upstream for 4787 feet. The Phase 1 Assessment determined that this reach was, by reference, a "C" type channel in a narrow valley with predominately plane bed features. The development of Vermont Route 100 through the corridor of the North Branch has effectively reduced the original floodplain and altered the valley width of this reach to a semi-confined channel. This loss of floodplain may have led to historic degradation. The incision ratio was measured to be 1.72. Today, there exists major aggradation, minor widening and planform adjustment. The entrenchment ratio of the segment remains low and therefore it will probably continue to widen and attempt to rebuild a new floodplain. Bank erosion and riprap, which account for approximately a quarter of the total streambank surface indicate, active planform adjustment. Despite these active adjustment processes, the channel remains a "C" type (Figure 17).

Figure 17: Reach T2.05 is a predominately plane bed "C" type channel that has historically incised and is currently exhibiting major aggradation and minor widening and planform adjustment.

3.2.6 Reach T2.06

Reach T2.06 is a short reach of only 1245 feet that is undergoing major channel adjustments. The reach begins where the valley width of the North Branch widens and ends at the confluence of Bill Brook (T2.06-S1.01). This reach is a "C" type channel by reference that flows through a mixture of land uses; predominately hay and forest. The channel has undergone some minor historic channel degradation. The dominate adjustment process affecting this reach is extreme historic channel widening. This widening has resulted in bank erosion along over a third of the reach (Figure 18). Currently there is major aggradation exhibited by several mid channel and point bars.

Major planform adjustments occurring within the reach are evident by a historic channel avulsion and several flood chutes mapped by BCE scientists. Currently, the channel is narrowing through aggradation. It has established a new juvenile floodplain and is once again a "C" type channel that may continue to adjust in the coming years as it works to regain a dynamic equilibrium.

Figure 18: Bank erosion along reach T2.06. The channel is attempting to narrow through major bar development along the left bank.

3.2.7 Reach T2.07

North Branch reach T2.07 begins at the confluence with Bill Brook (T2.06-S1.01) and ends 4149 feet upstream where Ellis Brook (T2.07-S1.01) joins the main channel. By reference, Phase 1 assessment data has indicated that this should be a "C" type channel in a very broad valley. Historic channel realignment and straightening, however, has caused major historic channel degradation. The current channel incision ratio is 2.2. Without adequate access to its floodplain, reach T2.07 is undergoing major widening, planform adjustment, and aggradation. The combination of adjustments has caused a stream type departure to an "F" channel with a weak riffle-pool structure (Figure 19).

Figure 19: Reach T2.07 has become an "F" channel with a weak riffle-pool bed form.

3.2.8 Reach T2.08

North Branch reach T2.08 begins at the confluence with Ellis Brook (T2.07-S1.01) and ends upstream where Blue Brook (T2.08-S1.01) joins the main river channel. A change in channel confinement occurred in the upper third of the reach due to the berming of the left bank and the routing of Route 100 on the right bank. The result was a change in existing stream type that prompted BCE scientists to break the reach into two segments.

Segment T2.08-A

Segment T2.08-A begins at the confluence of Ellis Brook. The reach flows for 1500 feet through a golf course. Vermont Route 100 runs along the right bank for 430 feet at the upstream end of the segment. The golf course and road have significantly impacted the riparian buffer of this segment. The dominant buffer width on both sides of the river has been reduced to less than five feet wide. This segment has also been significantly altered by historic channel straightening. These alterations and encroachments on the floodplain may have contributed to streambed incision. The current incision ratio was measured to be 1.71 indicating significant historic degradation. Several mid-channel bars and steep sedimented riffles indicate a large amount of aggradation has been occurring in the reach. Indications of minor planform adjustment and widening were also observed.

By reference, this segment is likely a riffle-pool "C" type channel. While it remains a "C" type channel, straightening and incision have caused the bedform to become a plane bed system which now lacks pool habitat (Figure 20). Continued aggradation and planform adjustment may be expected while the channel continues to redevelop.

Figure 20: Typical cross-section along the plane bed form of segment T2.08-A.

Segment T2.08-B

Segment T2.08-B runs adjacent to North Branch Fire District #1's spray disposal site in West Dover. In order to keep the North Branch from flooding into the spray site, a berm has been created that runs along the entire left bank of this segment. On the right bank, Vermont Route 100 has pinned the river into a straight reach with minimal floodplain access. The extensive floodplain encroachment has caused a very broad river valley to become narrowly confined. The river has departed from its natural "C" channel type to an “F” type channel. The departure occurred as the river, without floodplain access, incised into its bed (the existing incision ratio was measured to be 2.1). Following this incision, the river has widened into an “F” type channel losing its riffle-pool features and turning into a plane bed form (Figure 21).

Currently the river appears to be under major adjustment from aggradation and widening, and minor planform adjustment. The reach is further impacted by riparian buffer removal which has reduced streamside vegetation to less than five feet in width from the top of each bank.

Figure 21: Typical cross-section along segment T6.08-B.

3.2.9 Reach T2.09

North Branch of the Deerfield River reach T2.09 begins where the valley wall naturally closes the floodplain into a semi-confined valley. This narrowing of the valley wall, which would create a "B" type plane bed channel by reference, has been further narrowed by the artificial valley wall created by Vermont Route 100. Route 100 runs along the right bank in over three quarters of this reach. This change in entrenchment has led to a narrowly confined channel which has lost access to its historic floodplain.

Floodplain encroachment may have contributed to historic bed degradation. The historic degradation of this reach is confirmed by the incision ratio which was measured to be 3.8. Following degradation, the channel has been undergoing major widening and aggradation, and also minor planform adjustment as it attempts to regain some sinuosity. The planform adjustment and aggradation are evident through multiple side bars and a single flood chute that were found within this reach. In its wide, entrenched state, the existing stream type is an "F" channel (Figure 22).

While streambank stability has been enhanced by the forested valley wall which runs along the left bank, most of the riparian buffer on the right bank has been removed to less than 5 feet of width in order to accommodate Route 100.

Figure 22: Typical cross-section along reach T2.09, a plane bed "F" type channel

3.2.10 Reach T2.10

Reach T2.10 starts where the valley wall of the North Branch opens up downstream of West Dover Village and continues upstream through the village to the confluence with Blue Brook (T2.10-S1.01). At the point where Blue Brook enters the North Branch, the main channel almost doubles its drainage area. By reference, this reach should be a "C" type channel in a very broad valley with a riffle-pool bed form. Like many reaches on the North Branch, however, the floodplain of this reach has been greatly altered by channelization and development associated with Vermont Route 100, other town roads, and the Village of West Dover. The straightening and floodplain encroachments of this "C" channel have caused historic degradation of the streambed. Incision was followed by channel widening to its current "F" stream type. This new channel type does not support a riffle-pool system, and is instead a plane bed form (Figure 23). In response, the channel is undergoing major aggradation, planform adjustment, and widening, as it attempts to recreate a new floodplain bench and redevelop some meanders. In a natural setting the channel would develop back into a "C" stream type, however, development within the river corridor and stream bank armoring (3600 feet total currently) will likely prevent the evolution of this reach back to a “C” channel.

In addition to the impacts to the channel and floodplain, the encroachment of the Village has led to several other impairments. BCE scientists surveyed seven stormater inputs during the assessment of this reach. Additionally, the riparian buffer has been reduced to less than five feet in width along most of the reach.

Figure 23: Reach T2.10 has incised and widened into an “F” plane bed stream.

3.2.11 Reach T2.11

North Branch reach T2.11 begins at the confluence with Blue Brook (T2.10-S1.01) and continues upstream to Snow Lake. The upper section of the stream was found to be heavily influenced by beaver dams and therefore was segmented by BCE scientists.

Segment T2.11-A

Segment T2.11-A begins at the confluence of Blue Brook (T2.10-S1.01) and continues upstream for almost 10,000 feet to a point upstream of Tannery Road where the first of several beaver dams was found to be altering the flow and sediment transport of the

North Branch. By reference, this segment flows through a broad valley and has a "C" riffle-pool stream type. However, the retention of sediments created by the damming of Snow Lake may have caused major historic degradation within this reach (current incision ratio is 2.1). This degradation, coupled with some floodplain development, berming, and roadways have caused the channel to become semi-confined. In response to channel confinement and degradation the stream has undergone major widening and minor planform adjustment (indicated by several flood chutes and an island) to try and recreate a floodplain at a lower elevation. The existing stream type is an "F" channel on the border of becoming a "B" on its way back to a "C" type channel. In addition to degradation, Snow Lake is also causing major aggradation of the stream channel. This opposite effect may be created when major storm events stir up the sediment at the bottom of Snow Lake and transport it downstream into this reach. BCE and ANR scientists found evidence of major aggradation in this reach in the form of multiple mid, point, side, and diagonal bars. Both the historic degradation and current aggradation have caused the riffle-pool form to become plane bed resulting in a loss of habitat for aquatic biota (Figure 24).

Despite these drastic changes to the channel profile planform, the riparian condition of this stream has been relatively unaltered. There exists over 100 feet of healthy mixed forest on either bank of this segment.

Figure 24: Segment T2.11-A has historically incised and widened into an "F" channel with a plane bed form.

Segment T2.11-B

Segment T2.11-B begins at a beaver dam several hundred feet upstream of Tannery Road (Figure 25) and continues upstream to the Snow Lake Dam (T2.12). Due to the heavy influence of the beaver dams, BCE and ANR scientists were unable to conduct a full geomorphic assessment of this segment.

Figure 25: A partial assessment of Segment T2.11-B was performed due to beaver activity which is altering the flow and sediment transport of the reach.

3.2.12 Reach T2.12

North Branch reach T2.12 begins at the Snow Lake dam and ends at the upstream end of the lake at the lower end of reach T2.13 (Figure 26). This reach is a lentic system due to the impoundment and was not assessed in the Phase 2 Assessment.

The impoundment is disrupting the natural flow of water and sediment in the North Branch system. Coarse sediments are falling out of the system and are being dredged periodically to maintain the lake. Downstream of the impoundment, the system may be impoverished of sediment and has likely reacted by degrading the streambed and eroding its banks.

Figure 26: Looking at the start of Reach T2.13. Reach T2.12 was not assessed due to the impoundment of Snow Lake.

3.2.13 Reach T2.13

The North Branch reach T2.13 begins where the influence of the Snow Lake impoundment ends (Figure 26) and continues upstream for approximately 3000 feet to where the slope of the stream channel increases and reach T2.14 begins. Reach T2.13 was split into three segments by BCE scientists due to a change in stream type and bed substrates that were observed during the Phase 2 assessment.

<u>Segment T2.13-A</u>

North Branch segment T2.13-A is a short segment of almost 700 feet that begins at Snow Lake and ends at a bedrock ledge. Within this segment the channel slope becomes more gradual as the steep headwaters of the North Branch flatten and the valley walls open up. At the lower end, Snow Lake sets the slope of the channel. By reference, this stream is a “C” channel. Despite major channel straightening, armoring, development and the berming of 400 feet of streambank, the channel has retained its “C” stream type with a weak riffle-pool bedform (Figure 27).

During the Phase 2 assessment BCE scientists noted evidence of minor degradation, aggradation, widening and planform adjustment. An incision ratio of 1.7 confirms historic degradation. The stream, however, has been kept from excessive widening and floodplain redevelopment through berming and armoring activities. Bank armoring on the right bank totals 480 feet while 220 feet of the left bank have been armored. The stream buffer on both sides has been removed to less than five feet.

Figure 27: Typical cross-section along reach T2.13-A.

Segment T2.13-B

Segment T2.13-B begins at a bedrock ledge and continues upstream for 1500 feet until reaching a tributary and the start of a bedrock dominated channel. Despite development in the floodplain, this segment has retained its reference "B" stream type (Figure 28). Bedrock grade control at the upstream and downstream end has likely assisted in stream channel stability. Degradation within this reach was very minor. Additionally, only minor aggradation, widening, and planform adjustments were found to be occurring.

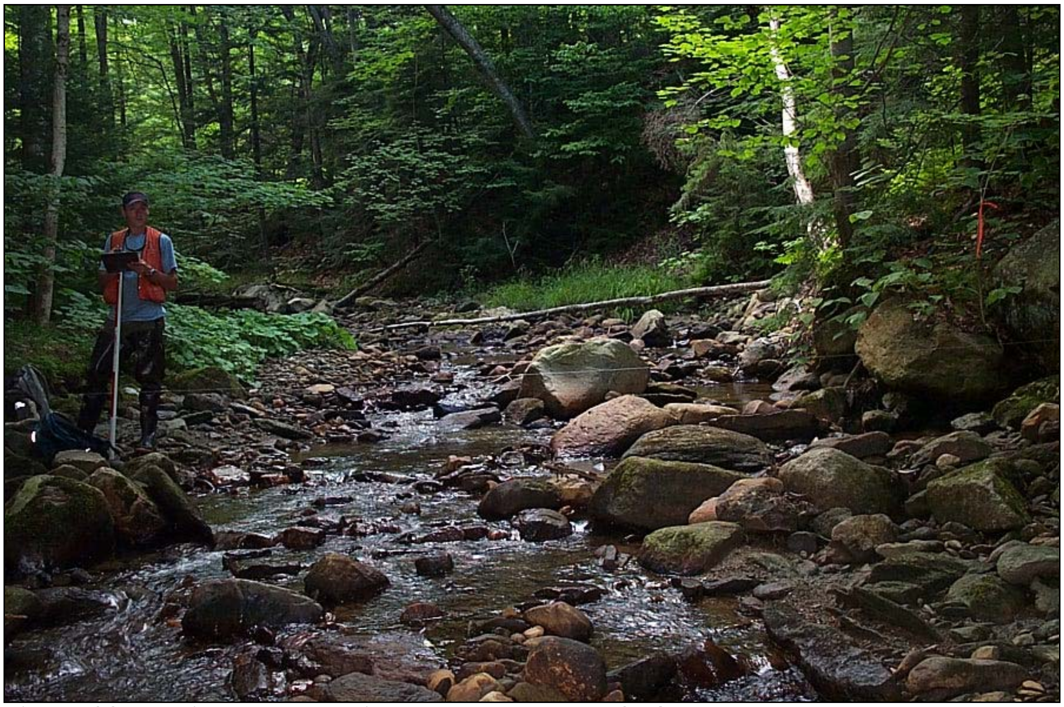

Figure 28: Typical cross-section along segment T2.13-B.

Segment T2.13-C

North Branch segment T2.13-C is dominated by a bedrock bottom (Figure 29). The segment is approximately 1000 feet in length and ends just downstream of the North Access Road. This reach was classified as a "B" channel dominated by bedrock substrate. Very minor corridor impacts and a relatively healthy riparian buffer (Averaging between 50 and 75 feet wide) have added to the overall stability of this segment. Excess sediment introduced into the channel via four stormwater outfalls is leading to excess sedimentation of this reach. This sediment and stormwater is filling in pools and also causing some minor widening and planform adjustments.

Figure 29: Segment T2.13-C is dominated by a bedrock bottom which creates a predominately cascade bedform.

3.2.14 Reach T2.14

Reach T2.14 begins just downstream of the North Access Road near Mount Snow Ski Resort and continues upstream into the headwaters of the North Branch. This stream was broken into four segments by BCE scientists as part of the phase 2 stream assessment.

Segment T2.14-A

The first segment investigated by BCE scientists is a deeply incised channel that has departed from its reference "C" stream type. The segment runs for 1270 feet upstream of the bedrock ledges in reach T2.13-C to where a steep riffle marks the end of the degraded segment. The reach has been historically straightened and the otherwise broad valley has been confined by roads and residential development into a narrowly confined channel. This channel confinement has caused major historic degradation that has resulted in an incision ratio of 2.2 (Figure 30) The stream type is currently a "G" channel that is undergoing minor aggradation, widening, and planform readjustment as it attempts to redevelop a new floodplain. Channel adjustment is causing moderate bank erosion on at least one-quarter to one-third of the segment. Many leaning trees and exposed roots confirm the widening and planform adjustment processes (Figure 30).

Figure 30: Typical cross-section along the highly incised "G" stream type of segment T2.14-A.

Segment T2.14-B

North Branch segment T2.14-B is a "C" channel with a riffle-pool bedform (except where the slope increases and a few step-pools appear). The reach begins near the most upstream residential development on the North Branch and continues upstream to a change in slope where segment T2.14-C begins. Unlike most reaches along the main stem of this watershed, segment T2.14-B has no recorded encroachments in its river corridor. As a result the stream has not undergone any major channel adjustments. The riparian buffer remains well intact and contributes to the overall stability of this reach (Figure 31). BCE scientists found no major or minor adjustment processes occurring within this segment.

Figure 31: Typical cross-section along segment T2.14-B, which is surrounded by a healthy riparian corridor and has retained access to its floodplain.

Segment T2.14-C

Segment T2.14-C has remained relatively undisturbed. This segment is a "B" stream type on a steep slope of 11.5% (Figure 32). The riparian buffer remains well intact and contributes to the overall stability of this reach. BCE scientists found no major or minor adjustment processes occurring within this reach.

Figure 32: Typical cross-section along segment T2.14-C

Segment T2.14-D

Segment T2.14-D has also remained relatively undisturbed (Figure 33). The channel was not assessed due to the remoteness of the site, difficult access, and the very small drainage area.

Figure 33: Typical cross-section along segment T2.14-D near the headwaters of the North Branch.

4.0 GEOMORPHIC CONDITION

Understanding the response to changes in the sediment regime, hydrology, the channel area and planform of the North Branch is highly useful for informing restoration efforts. Such responses are influenced by past channel management, the current condition, channel evolution processes that are occurring within the reach, and the sensitivity of the stream to these changes.

4.1 Channel and Floodplain Management History

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

- Gravel extraction from the streambed and floodplain
- Forest clearing
- Channelization and bank armoring
- Removal of woody riparian vegetation
- Floodplain encroachments
- Urbanization
- Poor road maintenance and installation of infrastructure (Figure 34)
- Loss of wetlands

These anthropogenic practices have altered the delicate balance between water and sediment discharges within the watershed. A channel morphologic response to these practices contributes 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)

Figure 34: Undersized culverts disrupt the sediment transport capacity of the stream and may lead to both upstream and downstream destabilization. Improperly sized structures, such as this one on T2.13-A, can interfere with sediment transport and create scour below the structure.

4.2 Reach Condition

The reach condition is determined using the Rapid Geomorphic Assessment protocol, and is based on the degree of departure of the channel from its reference stream type (VANR 2005b). Of the 19 assessed segments, only two (T2.14-B and T2.14-C) were found to be in reference geomorphic condition. Both of these reaches are located at the top of the study area in the forested headwaters of the North Branch. Only two reaches (T2.13-B and T2.13-C) were found to be in good geomorphic condition, exhibiting only minor adjustment processes. Fourteen of the 19 sections were only in fair condition. These segments were currently undergoing major adjustments through aggradation, widening, and/or a change in their planform. Only one segment, T2.10, a highly altered reach which flows through the Village of West Dover, was found to be in poor geomorphic condition. Table 4 and Figure 35 present the geomorphic condition of the streams within the study area.

Table 4. Phase 2 Geomorphic Condition for North Branch			
Segment Number	**Existing Stream Type**	**RGA Score**	**Reach Condition**
T2.02	F4	0.45	Fair
T2.03-A	F4	0.51	Fair
T2.03-B	C4	0.58	Fair
T2.04-A	C4	0.48	Fair
T2.04-B	B4c	0.51	Fair
T2.05	C4	0.48	Fair
T2.06	C4	0.40	Fair
T2.07	F4	0.40	Fair
T2.08-A	C4	0.55	Fair
T2.08-B	F4	0.41	Fair
T2.09	F4	0.41	Fair
T2.10	F3	0.34	Poor
T2.11-A	F3	0.46	Fair
T2.13-A	C4b	0.64	Fair
T2.13-B	B3	0.65	Good
T2.13-C	B1	0.69	Good
T2.14-A	G3	0.50	Fair
T2.14-B	C4b	0.85	Reference
T2.14-C	B3a	0.95	Reference

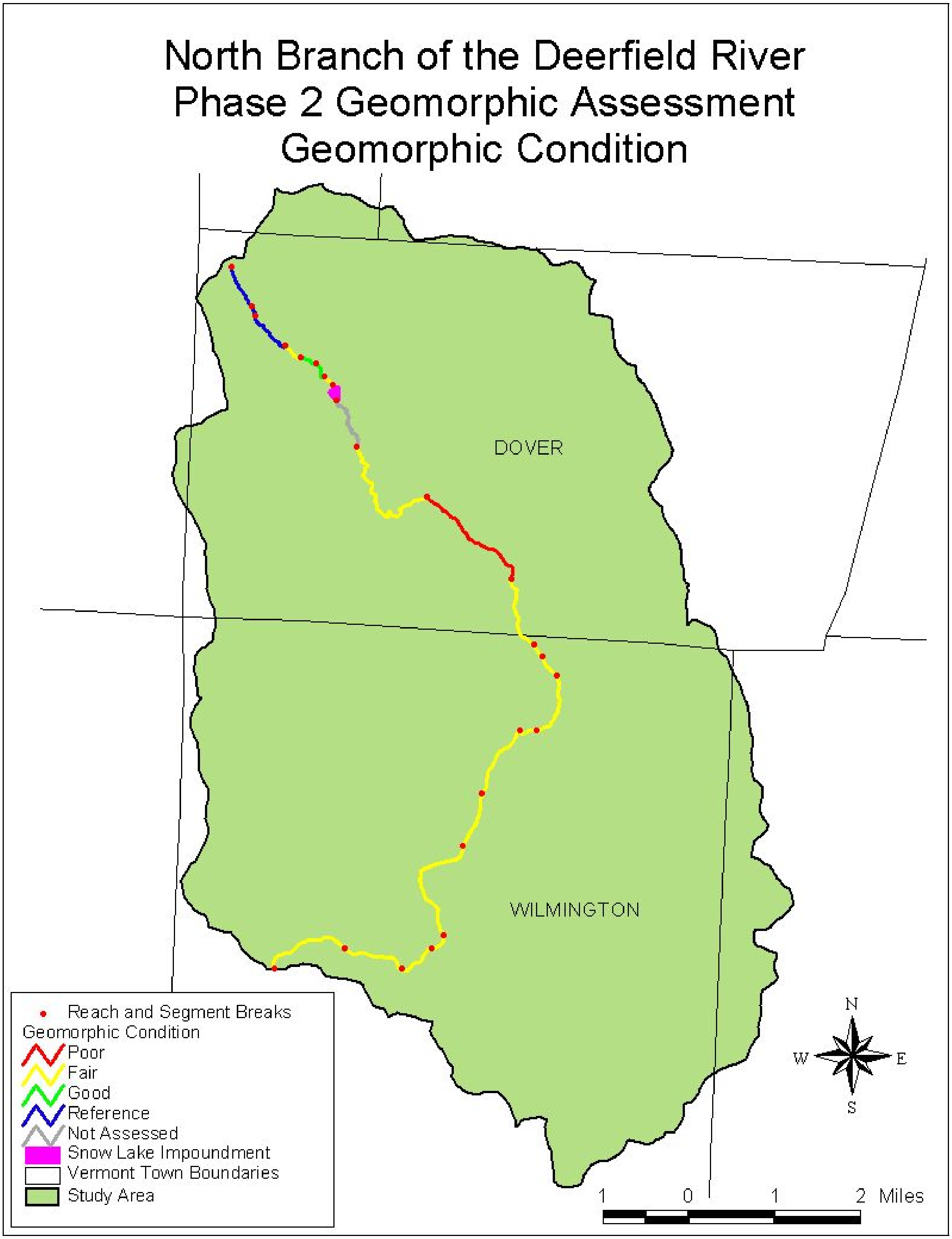

Figure 35: Phase 2 Geomorphic Condition of the North Branch of the Deerfield River

4.3 Channel Evolution

The reach condition ratings of the North Branch indicate that many of the reaches are actively, or have historically, undergone a process of minor or major geomorphic adjustment. The most common adjustment processes in the North Branch are widening and planform migration as a result of historic degradation within the channel. Degradation is the term used to describe the process whereby the stream bed lowers in elevation through erosion, or scour, of bed material. Aggradation is a term used to describe the raising of the bed elevation through an accumulation of sediment. The planform is the channel shape as seen from the air. Planform change can be the result of a straightened course imposed on the river through different channel management activities, or a channel response to other adjustment processes such as aggradation and widening. Channel widening occurs when stream flows are contained in a channel as a result of degradation or floodplain encroachment, or when sediments overwhelm the stream channel and the erosive energy is concentrated into both banks.

The quantity and size of sediment that is being transported by a stream 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. The common 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 of elevation.

Most of the reaches studied in the North Branch watershed are undergoing a channel evolution process in response to large scale changes in its sediment, slope, and/or discharge associated with the human influences on the watershed. Table 5 refers to the channel evolution of each study reach and the primary adjustment processes that are occurring. The RGA scores for each adjustment process (e.g. degradation, aggradation, widening, and planform) is summarized on page 43 of Appendix B.

Table 5. Stream Type and Channel Evolution Stage

Segment Number	Entrenchment Ratio	Width to Depth Ratio	Reference Stream Type	Existing Stream Type	F-Stage Channel Evolution	Major Active Adjustment Process
T2.02	1.3	21.4	B4	F4	III	Aggradation **Widening** Planform
T2.03-A	1.4	19.7	B4c	F4	II	Aggradation Widening Planform
T2.03-B	5.2	20.0	C4	C4	III	**Aggradation** Widening Planform
T2.04-A	3.1	19.6	C4	C4	IV	**Aggradation** **Planform** Widening
T2.04-B	1.7	19.1	C4	B4c	II	Aggradation Widening Planform
T2.05	3.8	22.0	C4	C4	III	**Aggradation** Widening Planform
T2.06	4.3	42.3	C4	C4	IV	**Aggradation** **Widening** **Planform**
T2.07	1.2	30.0	C4	F4	**III**	**Aggradation** **Widening** **Planform**
T2.08-A	18.5	20.5	C4	C4	III	**Aggradation** Widening Planform
T2.08-B	1.2	18.1	C4	F4	III	**Aggradation** **Widening** Planform
T2.09	1.5	24.7	B4c	F4	III	**Aggradation** **Widening** Planform
T2.10	1.1	20.3	C3	F3	III	**Aggradation** **Widening** **Planform**
T2.11-A	1.3	22.1	C3	F3	III	**Aggradation** **Widening** Planform
T2.13-A	3.2	12.1	C4b	C4b	III	Aggradation Widening Planform

Table 5. Stream Type and Channel Evolution Stage

Segment Number	Entrenchment Ratio	Width to Depth Ratio	Reference Stream Type	Existing Stream Type	F-Stage Channel Evolution	Major Active Adjustment Process
T2.13-B	1.7	12.2	B3	B3	IV	Aggradation Widening Planform
T2.13-C	1.4	20.3	B1	B1	IId	Aggradation Widening Planform
T2.14-A	1.2	9.1	C3	G3	II	Aggradation Widening Planform
T2.14-B	2.7	12.6	C4b	C4b	I	None
T2.14-C	1.9	5.7	B3a	B3a	I	None

Bold Black lettering – denotes major adjustment process
Black lettering (no bold) – denotes minor adjustment process

In terms of channel evolution models, the North Branch and the lower reaches of its tributaries are predominately between stages III and IV of the "F-stage" channel evolution model (see Appendix C). In many reaches the channel has undergone historic degradation. Many of the cross sections on study reaches were found to be incised. The incision ratio ranged form 1.0 to 3.8. Eight of the nineteen segments were found to have a bankfull elevation that was at least one mean bankfull depth lower than the top of the low bank indicating a high level of bed degradation. Along many of the main stem reaches and near the mouths of the tributaries, the system has attempted to adjust to this lower bed elevation by moving laterally and widening in order to create a new floodplain at a lower elevation and to regain sinuosity lost through channel straightening. This widening and planform adjustment is leading to another adjustment process, aggradation. Aggradation in the North Branch study area seems to be a combination of autochthonous sediment that is created as the stream widens and erodes its banks to reestablish a new floodplain as well as from allochthonous sources such as gravel roads and land clearing. The combination of these channel responses in the North Branch has been a significant loss in habitat for aquatic species, degraded water quality, loss of public and private property, increased flood hazard, and reduced recreational opportunities.

4.4 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. Assigning a sensitivity rating to a stream is done with the assumption that some streams, due to their setting and location within the watershed, are more likely to be in an episodic, rapid, and/or measurable state of change or adjustment. A stream's inherent sensitivity may be heightened when human activities alter the setting characteristics that influence a stream's natural adjustment rate including: boundary conditions; sediment and flow regimes; and the degree of confinement within the valley. Streams that are currently in adjustment, especially those undergoing degradation or aggradation, may become acutely sensitive (ANR 2005b).

Figure 35 is a map presenting the existing stream types found in the North Branch watershed. The stream sensitivity of these reaches, generalized according to stream type as per the ANR protocol, is depicted in Table 6 and in Figure 36. In general the North Branch has many reaches that are very high to extremely sensitivity. The historic degradation and reduction of floodplain access in these reaches increases stream power in the channel making catastrophic geomorphic adjustment more likely.

Table 6. Stream Sensitivity for Phase 2 Reaches

Segment Number	Existing Stream Type	Stream Type Departure	Geomorphic Condition	Sensitivity
T2.02	F4	Yes	Fair	Extreme
T2.03-A	F4	Yes	Fair	Extreme
T2.03-B	C4	No	Fair	Very High
T2.04-A	C4	No	Fair	Very High
T2.04-B	B4c	Yes	Fair	High
T2.05	C4	No	Fair	Very High

Table 6. Stream Sensitivity for Phase 2 Reaches				
Segment Number	**Existing Stream Type**	**Stream Type Departure**	**Geomorphic Condition**	**Sensitivity**
T2.06	C4	No	Fair	Very High
T2.07	F4	Yes	Fair	Extreme
T2.08-A	C4	No	Fair	Very High
T2.08-B	F4	Yes	Fair	Extreme
T2.09	F4	Yes	Fair	Extreme
T2.10	F3	Yes	Poor	Extreme
T2.11-A	F3	Yes	Fair	Extreme
T2.13-A	C4b	No	Fair	Very High
T2.13-B	B3	No	Good	Moderate
T2.13-C	B1	No	Good	Very Low
T2.14-A	G3	Yes	Fair	Extreme
T2.14-B	C4b	No	Reference	High
T2.14-C	B3a	No	Reference	Moderate

Figure 36: Phase 2 Stream Sensitivity Map for the North Branch of the Deerfield River

5.0 HABITAT EVALUATION

The Rapid Habitat Assessment (RHA) is used to evaluate the physical components of a stream (the channel bed, banks, and riparian vegetation) and how the physical condition of the stream affects aquatic life. The results can be used to compare physical habitat condition between sites, streams, or watersheds, and also serve as a management tool in watershed planning or similar land-use planning.

Table 7 and page 44 of Appendix B below show a comparison of the habitat condition based on the Rapid Habitat Assessment (RHA) and the geomorphic condition based on the Rapid Geomorphic Assessment (RGA). For twelve of the nineteen segments, both the RHA and the RGA resulted in ratings of fair. Reach T2.04-A and T2.04-B had a rating of fair for geomorphic condition, but a rating of poor for habitat. Only two reaches, T2.14-B and T2.14-C, resulted in a reference rating for habitat condition (Figure 37). In general the study reaches lacked a strong riffle-pool bedform (many were plane bed or had pools that were filled with fine sediments) 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 (Figure 38). 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 North Branch is intricately tied to the geomorphic condition of the stream.

Table 7. Comparison of RHA and RGA for Phase 2 Reaches

Segment Number	Score RGA	Score RHA	Rating RGA	Rating RHA
T2.02	0.45	0.37	Fair	Fair
T2.03-A	0.51	0.49	Fair	Fair
T2.03-B	0.58	0.46	Fair	Fair
T2.04-A	0.48	0.35	Fair	Poor
T2.04-B	0.51	0.33	Fair	Poor

Table 7. Comparison of RHA and RGA for Phase 2 Reaches

Segment Number	Score RGA	Score RHA	Rating RGA	Rating RHA
T2.05	0.48	0.39	Fair	Fair
T2.06	0.43	0.40	Fair	Fair
T2.07	0.40	0.47	Fair	Fair
T2.08-A	0.55	0.48	Fair	Fair
T2.08-B	0.41	0.48	Fair	Fair
T2.09	0.41	0.49	Fair	Fair
T2.10	0.34	0.45	Poor	Fair
T2.11-A	0.46	0.54	Fair	Fair
T2.13-A	0.64	0.53	Fair	Fair
T2.13-B	0.65	0.62	Good	Fair
T2.13-C	0.69	0.63	Good	Fair
T2.14-A	0.50	0.58	Fair	Fair
T2.14-B	0.85	0.85	Reference	Reference
T2.14-C	0.95	0.93	Reference	Reference

Figure 37: Reach T2.14-B rated "reference" for habitat. The reach had in-stream woody habitat, excellent riparian vegetation and riparian buffer, a diversity of substrates, and a diversity of flows including several deep pools.

Figure 38: Reach T2.04-A rated "poor" for habitat. The reach lacked in-stream woody habitat, riparian vegetation, a riffle-pool system due to historic straightening, and was heavily embedded with fine particles of sand.

6.0 STORMWATER IMPAIRED REACHES

As noted in Section 1.1, the North Branch from Tannery Road to 0.2 miles upstream of Snow Lake is on the 2004 State of Vermont 303(d) list of impaired waters (Figure 3). Surface water quality problems noted in this section include: stormwater runoff, land development, and construction related erosion (VDEC 2004). This impaired section of the North Branch, as shown in Figure 39, includes Segment T2.13-A (above Snow Lake), the Snow Lake Impoundment, and Segment T2.11-B (below Snow Lake).

Instability in the North Branch begins at the top of segment T2.14-A. Here floodplain encroachment and channel straightening begin to affect the morphology of the channel, which has become highly incised. Bedrock within the channel at the top of reach T2.14-A may be preventing the channel from headcutting upstream into segment T2.14-B, which was found to be in reference geomorphic and habitat condition. In addition to channel incision, the first stormwater discharges empty into the channel (Personal communication Jim Pease 1/23/06). Habitat and geomorphic condition were assessed as fair, indicating major geomorphic adjustment processes and degradation of instream habitat.

The next segment downstream, T2.13-C, has a bedrock dominated channel, and is therefore more resistant to geomorphic adjustment. The geomorphic condition of this segment was rated as good. The bedrock grade control has prevented degradation and only minor aggradation, widening , and planform adjustment were noted. The habitat of this reach, however, was listed as fair largely due to sedimentation from both stormwater inputs and upstream instability. Pools in this segment were noted to be filled with fine sediment. Reach T2.13-B also rated in good geomorphic condition. It has floodplain access in many areas of the reach, and has been minimally altered. Habitat in this reach, however, was rated in fair condition and is also degraded due to sedimentation.

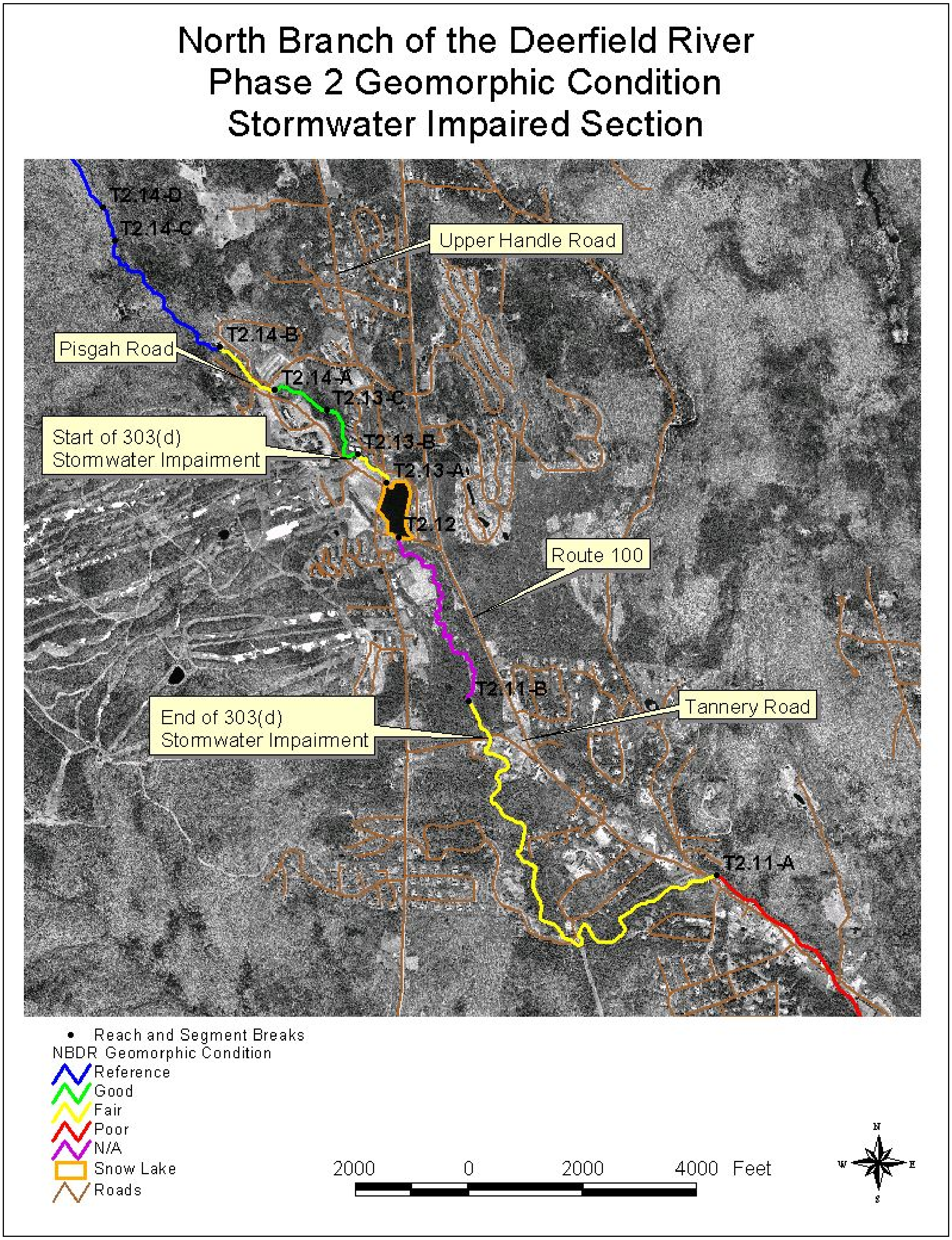

Figure 39. 303 (d) listed Stormwater Impaired Section of North Branch of Deerfield River

Segment T2.13-A, located immediately upstream of Snow Lake, has been significantly altered. The banks have been armored and some of the riparian vegetation has been removed. This segment has been straightened; floodplain access has been reduced by berming. Relocation of these berms back away from the top of the bank could be considered to restore floodplain access and provide attenuation of sediment, while still providing flood control to the parking lot. Sedimentation in segment T2.13-A may be a combination of stormwater discharges as well as instability upstream. In addition, the natural decline in channel slope may make this segment particularly susceptible to the impacts of excessive sediment within the system.

The geomorphic and habitat condition of Snow Lake could not be assessed using the ANR protocols because it is not a fluvial system. As discussed above in Section 3.2.1.2. (Reach T2.12), the impoundment is disrupting the natural flow of water and sediment in the North Branch system. Segment T22.11-B, also within the 303(d) impaired section, could not be assessed by the BCE project team due to the influence of numerous beaver dams within this segment. The low slope through this wetland area also makes this segment susceptible to impacts from excessive sediment that originates in the upper watershed. Only the very upper portion of segment T2.11-A falls within the 303(d) impaired section. This reach rated in fair geomorphic and habitat condition. Major sediment buildup within this reach, as well as evidence of widening and degradation, has caused major channel instability.

Addressing the 303(d) impaired waters in the North Branch of the Deerfield should be a combination of reducing sediment inputs from stormwater as well as channel restoration projects which reconnect reaches T2.11-A through T2.14-A with floodplain access to increase the ability of these channels to attenuate sediment in the floodplain.

7.0 RECOMMENDATIONS

Based on the 2005 Phase 2 Assessment of the North Branch watershed, Bear Creek

Environmental recommends the following:

1. Snow Lake is causing significant disruption to the transport of sediment and water through the North Branch system. BCE recommends conducting an Alternatives Analysis of this reach to examine the feasibility of taking this pond off line.

2. Implement stormwater control efforts whenever possible to reduce sedimentation. In particular, stormwater outfalls in reach (T2.13) in the vicinity of Mount Snow Lake were noted to be causing excess sedimentation resulting in the filling of pools and causing some minor widening and planform adjustments. Stormwater improvements within the villages of West Dover and Wilmington (T2.10 and T2.03) are also recommended.

3. Floodplain access is the most effective means at controlling streambank erosion and for streams to attenuate excess sediment. Encroachment in the North Branch watershed has led to loss of habitat and geomorphic instability. Reconnecting floodplains and floodplain wetlands would provide critical stormwater retention, sediment reduction, and would improve the overall health of the stream system.

4. The towns of West Dover and Wilmington should consider the adoption of a zoning ordinance(s) to strictly limit further floodplain encroachments and to protect riparian buffer zones.

5. Develop and implement 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. Within the middle of the Phase 2 study area (reach T2.05), this equates to a meander belt width of 334 feet (or approximately 166 feet on each side of the meander center line). The River Corridor Plan would also provide some structure for identifying river restoration and corridor protection project types and effective approaches.

6. The reaches in the upper most portion of the North Branch watershed have been minimally impacted by land use as they are surrounded by forested lands. Conservation of land surrounding these reaches will help protect the headwaters of the North Branch.

7. The reference stream type for much of the main stem of the North Branch of the Deerfield River 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.

8. Conduct a bridge and culvert survey of private and public structures to gather specific information about the impacts of stream crossings within the North Branch Deerfield watershed. Replace undersized structures when opportunities and/or funding become available.

9. Carefully consider the stream type, evolution stage, and sensitivity before conducting any active geomorphic restoration projects in the main channel of the North Branch Deerfield River.

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