

North Branch of the Deerfield River River Corridor Management Plan Dover and Wilmington, Vermont July 28, 2013



Prepared by:
Bear Creek Environmental, LLC
149 State Street, Suite 3
Montpelier, Vermont 05602



Prepared under contract to:
Windham Regional Commission
139 Main Street
Brattleboro, VT 05301



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1.0 EXECUTIVE SUMMARY

A stream geomorphic assessment of the North Branch of the Deerfield River was conducted by Bear Creek Environmental, LLC (BCE) in 2005. The 2005 study was funded by the State of Vermont Clean and Clear Program (now called Ecosystem Restoration Program) and prepared under contract to the Vermont Department of Environmental Conservation (DEC). The summary of the assessment, Phase 1 and 2 Stream Geomorphic Assessments: *North Branch of the Deerfield River Watershed* (BCE, 2006), will be referred to in this report. The 2006 report includes a recommendation to develop a River Corridor Management Plan (RCMP). The 2013 RCMP is prepared under contract to the Windham Regional commission (WRC) with funding provided by the Ecosystem Restoration Program and the Deerfield Enhancement Fund. A planning strategy based on fluvial geomorphic science (see glossary at end of report for associated definitions) was chosen because it provides a holistic, watershed-scale approach to identifying the stressors on river ecosystem health. The stream geomorphic assessment data can be used by resource managers, community watershed groups, municipalities and others to identify how changes to land use alter the physical processes and habitat of rivers. The stream geomorphic assessment data from 2005, along with reconnaissance field visits in 2012 and 2013, will be used to help focus stream restoration activities within the watershed and assist with town planning.

The North Branch of the Deerfield River was divided into fourteen reaches for the 2005 assessment, which encompassed approximately fourteen miles of stream channel. The assessment was helpful in identifying major stressors to the geomorphic stability and habitat condition in the North Branch of the Deerfield watershed. The 2005 study showed that the majority of the segments assessed resulted in a geomorphic condition of fair. Extensive channel alterations and road encroachments along the North Branch of the Deerfield River have occurred within downtown Wilmington and along Route 100, causing loss of floodplain and channel instability. The current geomorphic adjustment process, stream sensitivity, and stage of evolution are useful in project development in order to provide effective channel management.

A list of 20 potential restoration and conservation projects was developed during project identification. In conjunction with the Phase 2 data collected in 2005, more recent information

(post Tropical Storm Irene) was used to make recommendations that will result in long term geomorphic stability. Types of projects include: river corridor protection through easements, improving riparian buffers, improved stormwater management, riparian restoration, berm removals, restoration of a natural channel around Snow Lake, replacement of two culverts, and investigations into the removal of two old bridge abutments. The projects support the goals of the WRC and the VT DEC by protecting the State's water quality and preserving natural resources.

2.0 LOCAL PLANNING PROGRAM OVERVIEW

There are many scientific terms used in this river corridor plan, and the reader is encouraged to refer to the glossary at the end of the document. Important terms that are in the glossary are shown in italics the first time they are used in the text.

2.1 Overview

This project focuses on the North Branch of the Deerfield River main stem in Dover and Wilmington, Vermont. The main stem was assessed using the Vermont Agency of Natural Resources Phase 2 Stream Geomorphic Assessment protocol during summer 2005 for a total of 13.8 river miles. The Vermont River Management program has developed state-of-the-art Stream Geomorphic Assessment (SGA) protocols that utilize the science of *fluvial geomorphology* (fluvial = water, geo = earth, and morphology = land shape). Fluvial geomorphology focuses on the processes and pressures operating on river systems. The Vermont protocol includes three phases:

1. Phase 1 – Remote sensing and cursory field assessment;
2. Phase 2 – Rapid habitat and rapid geomorphic assessments to provide field data to characterize the current physical condition of a river; and
3. Phase 3 – Detailed survey information for designing “active” channel management projects.

2.2 River Corridor Planning Team

The river corridor planning team for the North Branch of the Deerfield River watershed is comprised of the Windham Regional Commission and the Vermont Department of Environmental Conservation. Funding for the project is provided through the Ecosystem Restoration Program and the Deerfield Enhancement Fund. John Bennett (WRC), Jolene Hamilton (Windham County Natural Resources Conservation District), Marie Caduto (DEC), and Shannon Pytlik (DEC) make up the steering committee for the project. Shannon Pytlik from the Vermont River Management Section of the DEC provided a quality control/assurance review of the stream geomorphic assessment data.

2.3 Local Project Objectives

The stream geomorphic assessment data are useful to resource managers, community watershed groups, municipalities and others for identifying how changes to land use alter the physical processes and *habitat* of rivers. The study results are also important for designing *restoration* and protection projects for the watershed. The Progress Report on River Basin Water Quality Management Planning During 2011 (VANR, 2012a) indicates that Basin 12, which includes the North Branch of the Deerfield River watershed, is in the Tactical Planning Process stage of basin planning. According to the Progress Report, \$26,336 was funded in 2012 for the Deerfield River watershed. The funding was acquired through four grants and is for buffer planting projects, two stream geomorphic assessments, and a biomonitoring project. Public outreach and the adoption of Fluvial Erosion Hazard Zones (FEH) are included as priorities in the 2012 plans. Shannon Pytlik (DEC) is currently creating FEH for the North Branch main stem. Once these zones are available, they will be incorporated into the corridor plan. The 2005 Phase 2 geomorphic assessment focused on the main stem of the North Branch of the Deerfield River and therefore projects developed for this River Corridor Management Plan will be focused on the main stem as well.

2.4 Goals of the Vermont River Management Program

The State of Vermont's River Management Program has set out several goals and objectives that are supportive of the local initiative in the North Branch of the Deerfield watershed. The state management goal is to, "manage toward, protect, and restore the fluvial geomorphic equilibrium condition of Vermont rivers by resolving conflicts between human investments and river dynamics in the most economically and ecologically sustainable manner" (Vermont Agency of Natural Resources, 2009b). The objectives of the Program include fluvial erosion hazard mitigation and sediment and nutrient load reduction, as well as aquatic and *riparian* habitat protection and restoration. The Program seeks to conduct river corridor planning in an effort to remediate the geomorphic instability that is largely responsible for problems in a majority of Vermont's rivers. Additionally, the Vermont River Management Program has set out to assist with funding and technical support to facilitate an understanding of river instability and the establishment of well-developed and appropriately scaled strategies to protect and restore river equilibrium.

2.5 Preliminary Project Identification and Prioritization

2.5.1 Reach Level and Site Specific Opportunities

The stream *reaches* evaluated in this study involve a variety of planning and management strategies which can be classified under one of the following categories: Active Geomorphic Restoration and Passive Geomorphic Restoration.

Active Geomorphic Restoration implies the management of rivers to a state of geomorphic equilibrium through active, physical alteration of the channel and/or *floodplain*. Often this

approach involves the removal or reduction of human constructed constraints or the construction of *meanders*, floodplains or stable banks. Active riparian buffer revegetation and long-term protection of a river corridor is essential to this alternative.

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

There are a number of programs and organizations available for river restoration and protection. These are as follows:

- ANR River Corridor Easement Program (RCE)
- ANR Ecosystem Restoration Program (ERP; formerly called Clean & Clear)
- USDA Farm Service Agency's Conservation Reserve Enhance Program (CREP)
- USFWS and VT DEC Trees for Streams (TFS)
- USDA NRCS Environmental Quality Incentives Program (EQIP)
- USDA NRCS Wildlife Habitat Incentives Program (WHIP)
- USDA NRCS Wetland Reserve Program (WRP)
- Connecticut River Watershed Council (CRWC)
- Vermont Community Foundation - Deerfield River Enhancement Fund (VCF)
- Vermont River Conservancy (VRC)

River Corridor Easement

The River Corridor Easement is designed to promote the long term physical stability of the river by allowing the river to achieve a state of equilibrium (where sediment and water loads are in balance). River corridor easements are vital for a passive geomorphic restoration approach and can also be used for conserving rivers that are in good condition (equilibrium). Rivers that are in equilibrium have access to their floodplains and therefore experience less *erosion* and negative impacts from flooding events. Corridor easements are a high priority for reaches that are not in equilibrium; these channels are experiencing channel adjustments, which are causing conflicts with current/future land-use expectations. Providing an easement on these reaches reduces the conflict and provides a long term solution to sediment storage and flood water attenuation needs.

- Easements are in perpetuity, meaning the agreement stays with the land forever.
- A onetime payment is received by the landowner for transferal of channel management rights to a second party (a land trust).
- Transferal of channel management rights means that the landowner would no longer be able to rock-line river banks or remove gravel for personal use.

- A RCE requires a minimum 50 foot buffer that floats with the river. No active land use is allowed within the buffer. The buffer can be actively planted or allowed to revegetate passively.
- The easement does not take away the agricultural land use rights, so the landowner could continue to crop or pasture the farm land mapped outside of the buffer, yet within the corridor, for as long as the river allows.

Ecosystem Restoration Program

The Ecosystem Restoration Program, formerly called the Clean and Clear Program, is a Vermont program designed to improve water quality by addressing one or more of the following areas: stream stability, protecting against flood hazards, enhancing in-stream and riparian habitat, reducing stormwater runoff, restoring riparian wetlands, enhancing the environmental and economic sustainability of agricultural lands. Funding is available for project identification, project development and project implementation. Vermont municipalities, local or regional governmental agencies, and non-profit organizations, and citizens groups are eligible to receive funding.

Conservation Reserve Enhancement Program

The USDA Farm Service administers a program called the Conservation Reserve Enhancement Program that helps agricultural producers to take farmland out of production in sensitive areas, such as river corridors. This helps to improve water quality and restore wildlife habitat.

- CREP can be either a 15 or 30 year contract to plant trees.
- 90% of the practice costs are covered with the remaining 10% either resting with the participants or potentially paid for by the US Fish and Wildlife Service. Examples of the practice costs include fencing, watering facilities, and trees. There are some costs that are capped, but generally all the practice costs can be paid through the program.
- To provide additional incentives to enroll in CREP, the program offers upfront and annual rental payments for the land where agricultural production is lost during the contract period.

Trees for Streams

Programs offered by the US Fish and Wildlife Service and the Vermont DEC to work with local partners and landowners to restore native streamside vegetation along river banks.

Environmental Quality Incentives Program

EQIP is a voluntary program available through the Natural Resources Conservation Service (NRCS) that provides financial and technical assistance to implement conservation practices to meet local environmental regulations. Owners of land in agricultural or forest production are eligible for the program. Contracts with landowners can be up to ten years in length.

Wildlife Habitat Incentives Program

WHIP is a voluntary program offered to landowners to improve wildlife habitat on their land. Owners of agricultural land, nonindustrial private forest land, and Native American land are eligible. Technical assistance and up to 75 percent cost-share is available to improve fish and wildlife habitat. WHIP was not federally funded for 2013; however, funding for similar conservation practices could be retained through EQIP.

Wetland Reserve Program

WRP is a voluntary program offered by NRCS to landowners to protect, restore and enhance wetlands on their property. NRCS provides technical assistance and financial support for projects that establish long-term conservation and wildlife practices and protection.

Connecticut River Watershed Council

Restoration, protection, and enhancement of the river, wetlands, and shore lands within the Connecticut River watershed are supported by funds from CRWC. Typical projects include guiding development, preventing erosion, restoring stream passage, and making sure hydropower and industrial permits are aligned to protect natural heritage for future generations.

Vermont Community Foundation

VCF invests and administers funds throughout Vermont that work towards the greater good of the community. VCF jointly manages grant making for the Deerfield River Enhancement Fund with the Community Foundation of Western Massachusetts. This fund was established by TransCanada in 1999 for the environmental preservation of the Deerfield River Watershed. Grants can be awarded for new initiatives, one-time special projects, or continuing funding for outstanding, existing programs. The next cycle application deadline is in 2015.

Vermont River Conservancy

VRC is a statewide nonprofit land trust that works to permanently conserve and protect special lands along the waters of Vermont. Through conservation easements, VRC has secured the long-term protection of 50 important sites throughout Vermont and continues to encourage other activities such as land stewardship and water quality protection. VRC works to improve Vermont's flood resiliency by converting flood-threatened private property to public open space for recreation and public access.

2.5.2 Watershed-Level Opportunities

There are a number of watershed-level opportunities available to improve the geomorphic stability and water quality of the North Branch of the Deerfield watershed. Watershed opportunities include the development and adoption of fluvial erosion hazard zones, improved stormwater treatment, and community stream clean-up activities.

Fluvial Erosion Hazard Zones

The purpose of defining Fluvial Erosion Hazard Zones is to prevent increases in man-made conflicts that can result from development in identified fluvial erosion hazard areas; minimize property loss and damage due to fluvial erosion; and prohibit land uses and development in fluvial erosion hazard areas that pose a danger to health and safety. The basis of a Fluvial Erosion Hazard Zone is a defined river corridor which includes the course of a river and its adjacent lands. The width of the corridor is defined by the lateral extent of the river meanders, called the meander belt width, which is governed by valley landforms, *surficial geology*, and the length and slope requirements of the river channel. The width of the corridor is also governed by the stream type and *sensitivity* of the stream. River corridors, as defined by the Vermont Agency of Natural Resources (2008a), are intended to provide landowners, land use planners, and river managers with a meander belt width which would accommodate the meanders and slope of a balanced or equilibrium channel, which when achieved, would serve to maximize channel stability and minimize fluvial erosion hazards. Information collected during the Phase 2 Assessment including reach sensitivity, reach condition, and stream type is used to develop these zones. The development of FEH overlay districts on the municipal level are recommended by the Vermont River Management Program (2010b) to improve stream stability, reduce flood losses, and enhance public safety. Additional information about FEH zones is available at (http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_vtfehq.pdf).

Stormwater Management

Stormwater runoff rates are of particular concern in urbanized and agricultural watersheds because stormwater runs off from impervious or sparsely vegetated surfaces rather than naturally infiltrating the soil. The cumulative effect of the increased frequency, volume, and rate of stormwater runoff results in increases in wash-off pollutant loading to streams and destabilization of stream channels.

3.0 BACKGROUND WATERSHED INFORMATION

3.1 Geographic Setting

3.1.1 Watershed Description

The North Branch of the Deerfield River is a major *tributary* of the Deerfield River, which drains into the Connecticut River (Figure 3.1). The North Branch of the Deerfield is 13.8 miles long, including the on-stream pond Snow Lake, and drains approximately 55.9 square miles of land. Generally flowing from north to south, the North Branch of the Deerfield River originates on the eastern slopes of the Green Mountain Range in Dover, Vermont, and empties into the Deerfield River (Harriman Reservoir) in Wilmington, Vermont. Most of its tributaries are steep flashy streams.

From its source in the Green Mountain National Forest in Dover, the *headwaters* of the North Branch of the Deerfield River flows south down the forested mountainside. As the

river flows through the Mount Snow Ski Resort base area it is impounded by Snow Lake, a lake created by the resort for snowmaking and aesthetics. Approximately two miles below Snow Lake, the river changes to an eastwardly direction. At the confluence with Blue Brook the river begins to flow southeast along Route 100 in Dover and then south along Route 100N in Wilmington. Less than a mile south of the Dover-Wilmington town boundary, Ellis Brook enters from the north. As Bill Brook enters the main stem, the North Branch of the Deerfield proceeds westward for a short distance and then continues south, continuing to flow along Route 100N. Generally flowing south after the confluence with Cold Brook, the main stem winds its way into the downtown of Wilmington. After crossing under Main Street, Beaver Brook enters from the east and the river begins to flow west to the confluence with the Deerfield River, which at that point is considered the Harriman Reservoir because it is impounded by the Harriman Dam in Whitingham.

3.1.2 Political Jurisdictions

The North Branch of the Deerfield River watershed is located in the towns of Wilmington and Dover in Windham County. This Phase 2 assessment focused on the river channel and *riparian corridor* within those towns.

3.1.3 Land-Use

A land cover layer (2002) was obtained from the Vermont Center for Geographic Information (VCGI) to present land-use within the North Branch of the Deerfield River watershed for the river corridor plan. The 2002 land cover data indicates that the watershed is 72% forested, 15% developed, 8% agricultural, 1% wetland, and 4% open water (Figure 3.2). While the North Branch of the Deerfield River watershed is dominated by forested land, agriculture and developed land are sub-dominant land-uses. Developed areas are concentrated within the river corridor of the main stem, especially in downtown Wilmington, West Dover, and within the vicinity of the Mount Snow Ski Area.

3.2 Geologic Setting

The North Branch of the River flows through a gentle *gradient* valley, except for the most upstream areas. Most of the main stem has a channel slope less than one percent. The upper main stem originates in the Green Mountain National Forest in Dover, where the valley slope is very steep and averages about ten percent. The valley gradient of the main stem drops to about four percent as the river flows through the Mount Snow Ski Resort area. After the Snow Lake impoundment, the slope drops to under two percent for the rest of the main stem, with most areas under one percent. The most downstream reaches are impounded by the Harriman Dam on the Deerfield River.

The North Branch of the Deerfield River watershed is located in the Green Mountain Province, a physiographic region of Vermont that extends the entire length of the state. This region is underlain by schists and phylites (Doolan, 1996). The bedrock geology of this region is

predominantly 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.

Natural Resource Conservation Service (NRCS) soils information for the North Branch of the Deerfield River watershed was acquired from the Vermont Center for Geographic Information. The dominant *surficial sediments* (sediment deposits above bedrock) within the North Branch of the Deerfield River valley are primarily glacial till, ice-contact deposits, and alluvium. Sub-dominant surficial sediments include glacial till, ice-contact deposits, alluvium, glacial lake, and other deposits.

3.3 Geomorphic Setting

Bear Creek Environmental conducted a Phase 1 assessment of the North Branch of the Deerfield River watershed that was completed in 2005 (Figure 3.3). The Phase 1 assessment included breaking the watershed into 48 *reaches*; the main stem was broken into 14 reaches. Each reach represents a similar section of the stream based on physical attributes such as valley confinement, slope, sinuosity, bed material, dominant *bedform*, land-use, and other hydrologic characteristics. Each reach point in Figure 3.4 represents the downstream end of the reaches on the main stem, which is the focus of this River Corridor Plan. The combined length of the 14 stream reaches assessed during the Phase 2 study is approximately 13.8 miles, with approximately 7.1 miles in Wilmington, 6.7 miles in Dover.

Reaches were divided further into *segments* during the Phase 2 investigation based on changes in channel conditions. A segment is distinct in one or more of the following parameters: degree of floodplain encroachment or channel alteration, *grade control* occurrence (e.g., ledge), channel dimensions, channel sinuosity and slope, *riparian buffer* and corridor conditions, and degree of flow regulation. Segments are labeled using letter notation (i.e., T2.11-A is the most downstream segment on Reach T2.11). The most downstream segment within a reach is labeled "A", the second from the reach point is "B", etc. The 14 Phase 2 reaches studied in 2005 were broken further into 22 segments based on field observations. Three segments were not assessed due to impoundments or a lack of water in the channel (most upstream segment), making a total of 19 assessed segments.

Reach T2.12 was not assessed because it is currently an on-stream pond (Snow Lake), although there are plans to restore this section of the North Branch to a fluvial system. There is a new permitted withdrawal from Cold Brook that is yet to be constructed (as of October 2012). As soon as it is developed and functions properly, the plan is to drain Snow Lake and restore the North Branch of the Deerfield in that area (VT DEC, 2012a). According to John Bennett (personal communication), part of Snow Lake may be used as a stormwater retention/treatment pond and a restored channel would be constructed around the lake.

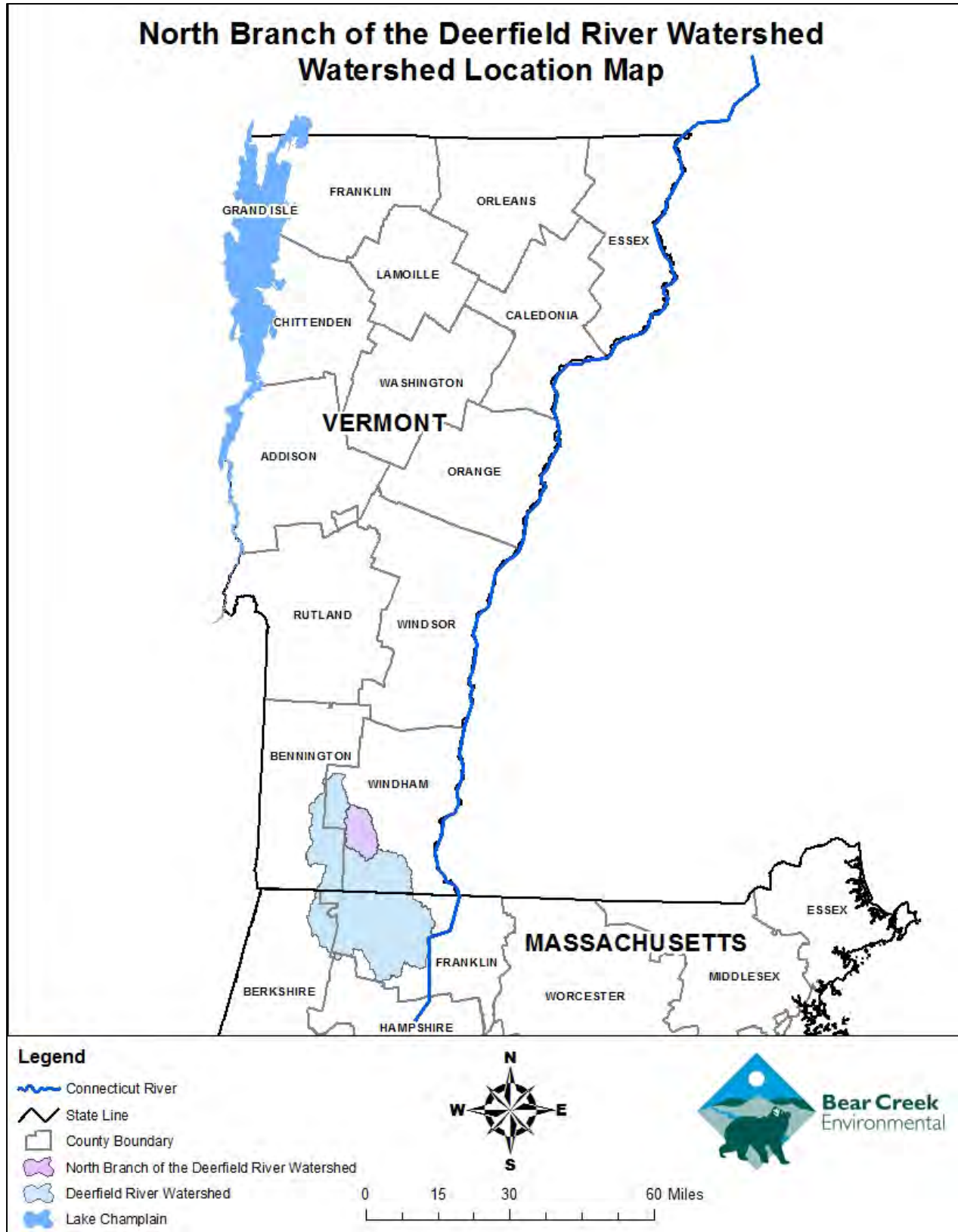


Figure 3.1. Watershed location map for the North Branch of the Deerfield watershed.

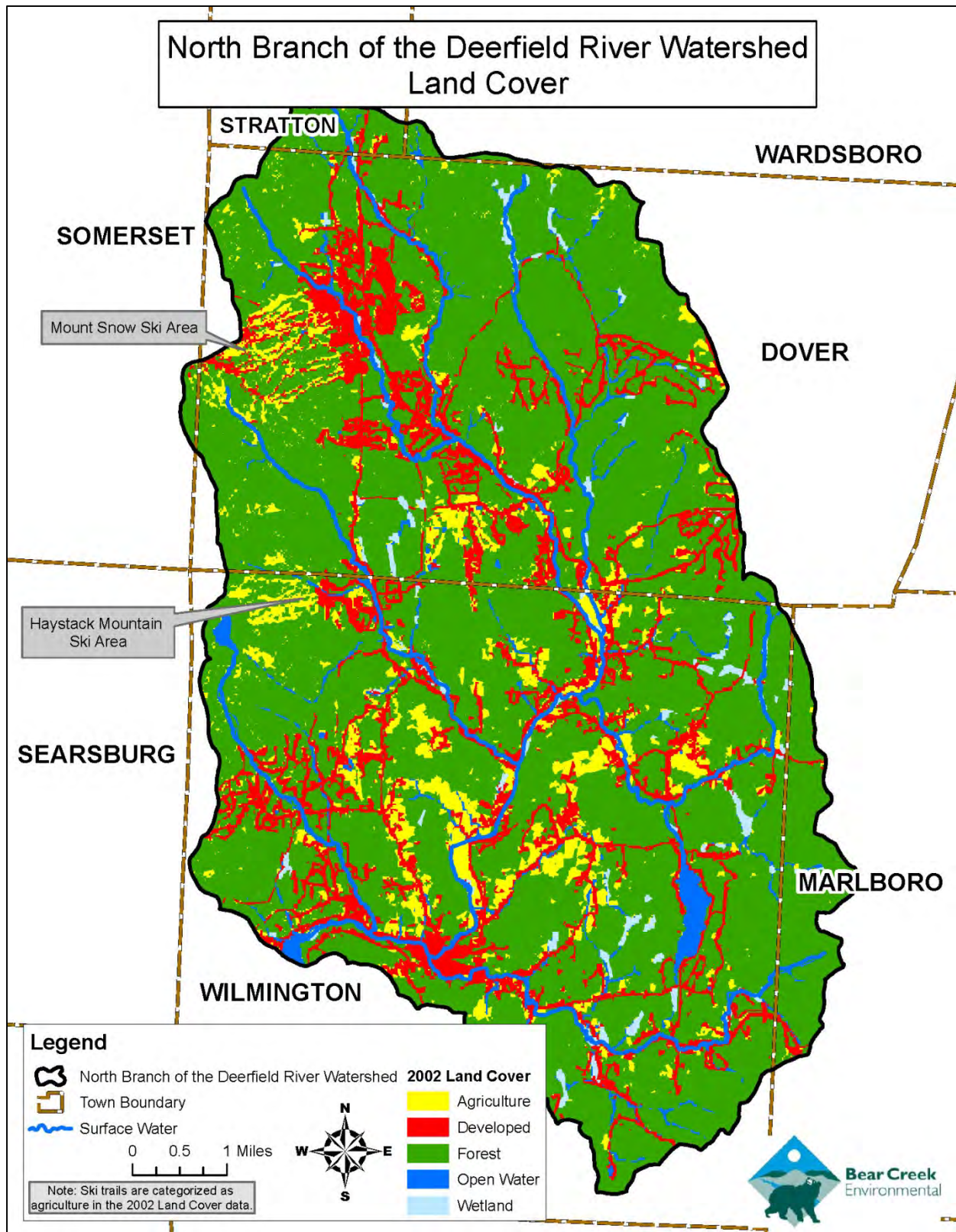


Figure 3.2. Land Cover and Land-Use Map for North Branch of the Deerfield River watershed.

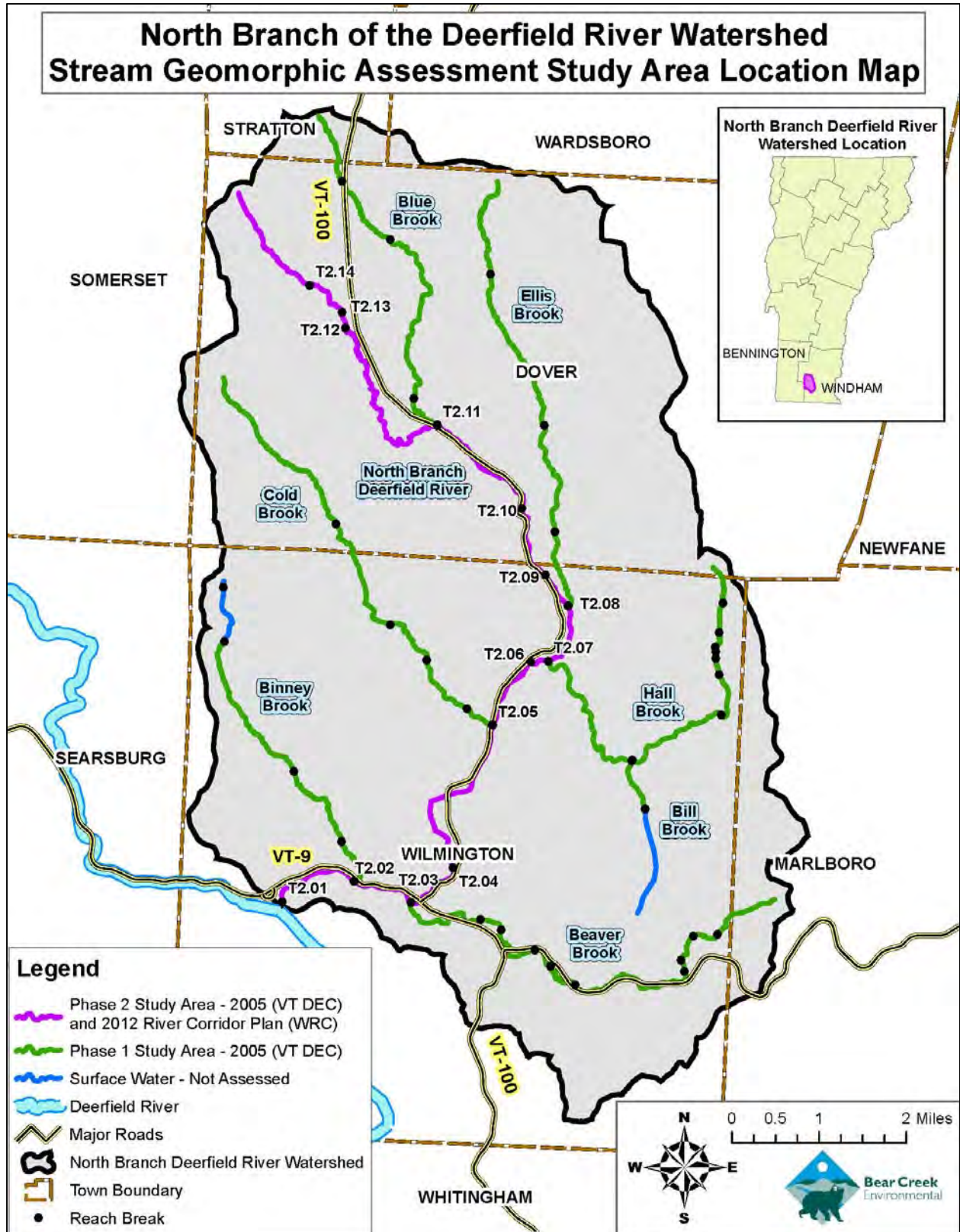


Figure 3.3. Phase 1 and 2 Stream Geomorphic Assessments completed in the North Branch of the Deerfield River watershed.

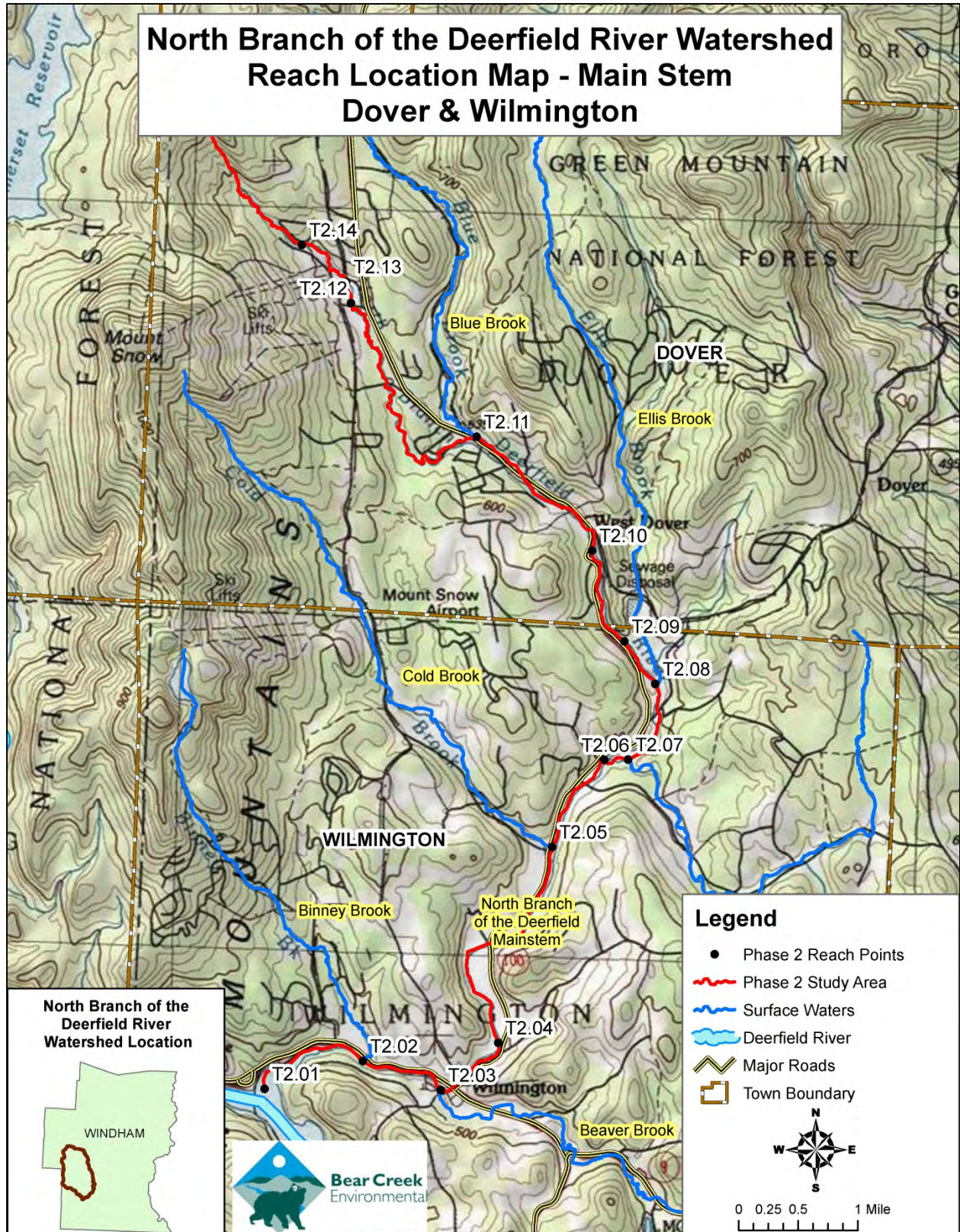


Figure 3.4. Reach location map for the North Branch of the Deerfield River main stem.

3.4 Channel Management History

Fred Nicholson, stream alteration engineer with the Vermont Agency of Natural Resources, was contacted in July 2005 by Pamela DeAndrea of Bear Creek Environmental for information regarding channel management activities 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 (Bear Creek Environmental, 2006).

3.5 Hydrology

In order to better understand the flood history of the North Branch of the Deerfield River, long-term data from the U.S. Department of the Interior, U.S. Geological Survey (USGS), were obtained (USGS, 2013). There are no USGS *gaging stations* within the North Branch of the Deerfield River watershed. Historical data from a nearby river was used in order to understand the hydrologic history of the North Branch of the Deerfield River watershed. Long-term data from USGS was obtained from the gage on the Walloomsac River near North Bennington, VT (gage #01334000). 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 large flood events. This gage has a continuous flow record from 1932 to the present.

Figure 3.5 shows the annual peak flows for the Walloomsac River USGS gage for the 81 years of record. Although provisional, the 2011 peak discharge of 9420 cubic feet per second (cfs) illustrates the magnitude of the flood event caused by Tropical Storm Irene (TSI) in August 2011. Tropical Storm Irene caused widespread flooding in Vermont with many areas receiving more than 7 inches of rain. Flood levels equaled or approached the historic flood of 1927 (Vermont Agency of Natural Resources, 2012b). The USGS is in the process of updating their flow statistics to take into account peak flow data from TSI (personal communication with Scott Olson on December 21, 2012).

Of all the natural hazards experienced in Vermont, flooding is the most frequent, damaging, and costly. During the period of 1995-1998 alone, flood losses in Vermont totaled nearly \$57 Million (Vermont Agency of Natural Resources, 2010b). The Vermont Agency of Administration (2012b) states that over 733 million dollars have been estimated in funding resources for Tropical Storm Irene recovery. Severe flooding at the confluence of the North Branch of the Deerfield River and Beaver Brook in downtown Wilmington from Tropical Storm Irene heavily impacted local homes and businesses. The worst property damage was seen in reach T2.02, which runs along Route 9. There are two property buyouts within the Town of Wilmington that

are currently in progress (personal communication with Alice Herrick, Zoning Administrator, Town of Wilmington, on March 14, 2013). According to Scott Murphy (Town Manager, Town of Wilmington), several bridges and culverts were heavily impacted by Tropical Storm Irene on the North Branch of the Deerfield tributaries. On the main stem, the Route 9 bridge in downtown Wilmington, near the intersection of Route 9 and Route 100, sustained damage to its wing walls as a result of TSI, but was deemed safe by the State of Vermont. While some flood losses are caused by inundation (i.e., waters rise, fill, and damage low-lying structures), most flood losses in Vermont are caused by “fluvial erosion.” Fluvial erosion is caused by rivers and streams, and can range from gradual bank erosion to catastrophic changes in river channel location and dimension during flood events (Vermont Agency of Natural Resources, 2010b). The VANR (2010b) attributes the high cost and frequency of fluvial erosion in Vermont to its geography (mountainous setting with narrow valleys and extreme climate) and past land-use practices (forest clearing).

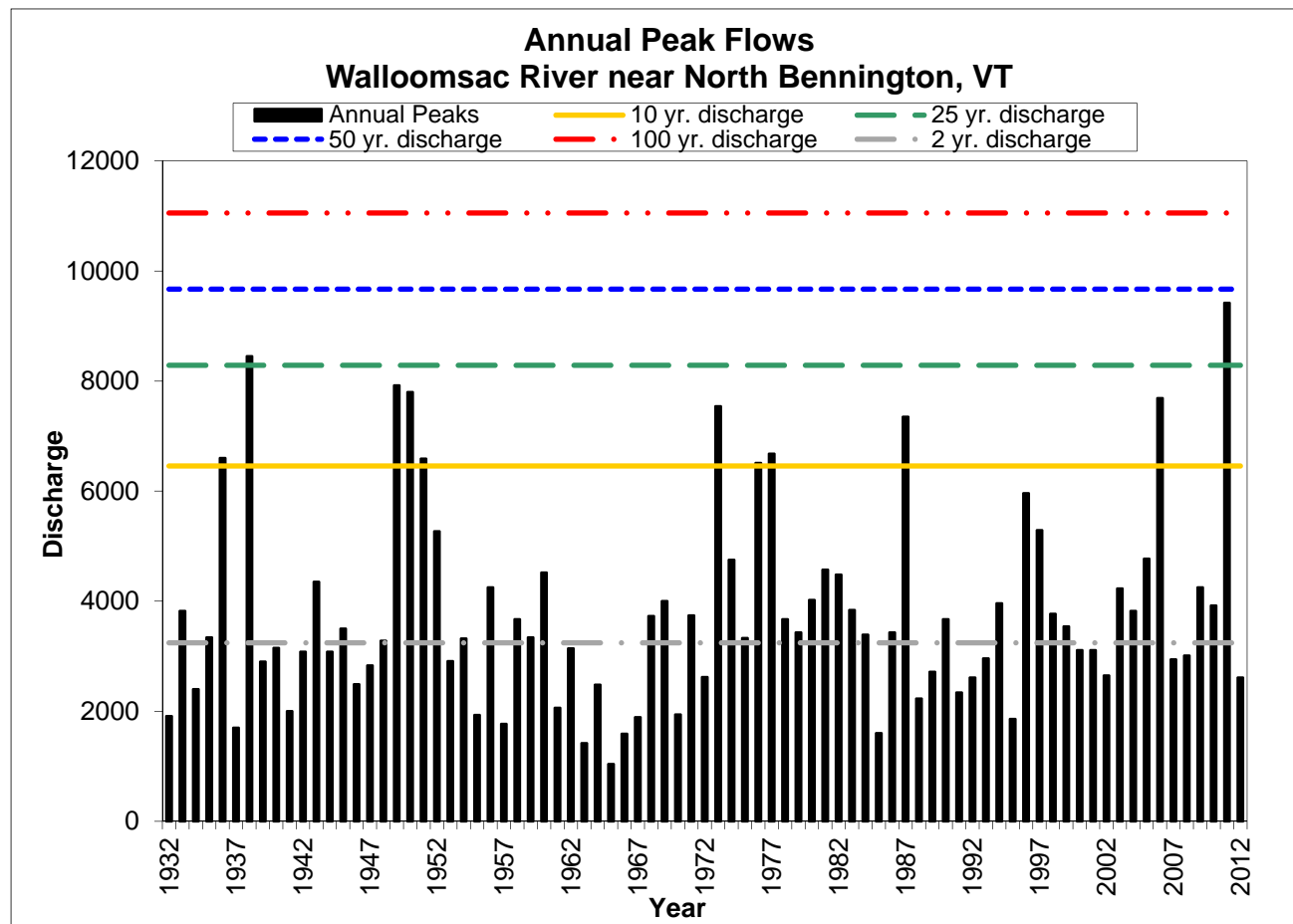


Figure 3.5. Annual Peak Flows for Walloomsac River at North Bennington, Vermont.

3.6 Ecological Setting

The North Branch of the Deerfield River watershed lies within the Southern Green Mountain biophysical region (See Figure 3.6). This region is characterized by Thompson and Sorenson (2000) as being hilly with numerous wetlands and rivers. The climate is moderate for Vermont and the elevation leads to a high average annual precipitation. Over 70 inches of rain and snow fall are seen in higher elevations and there are only a few areas that receive less than 50 inches per year. Northern hardwood forest is the dominant community in the Southern Green Mountain biophysical region.

The Vermont Significant Wetland Inventory (VSWI) GIS layer provides important information about the distribution of wetland habitat within the North Branch of the Deerfield River watershed (See Figure 3.6). The watershed has several scattered areas of intact wetlands. Snow Lake is mapped as a wetland in the VSWI; however it is a large on-stream pond.

According to Thompson and Sorenson (2000), black bear, white-tailed deer, bobcat, fisher, beaver, and red squirrel are common animals in the Southern Green Mountain biophysical region. The North Branch of the Deerfield is a cold water fishery with designated uses including swimming, fishing, and boating (VT DEC, 2008b). Wild brook and brown trout are supported in this watershed; brook trout are stocked on the main stem.

The Green Mountain National Forest is an important public land in the North Branch of the Deerfield River watershed. The Stephen Greene Municipal Forest (a.k.a. Stratton Town Forest), Dover Town Forest, land owned by the Town of Wilmington, and the Molly Stark State Park are other public lands that are within the watershed. The Tannery Wildlife Refuge is located adjacent to the North Branch of the Deerfield River, downstream of Mount Snow Ski Resort.

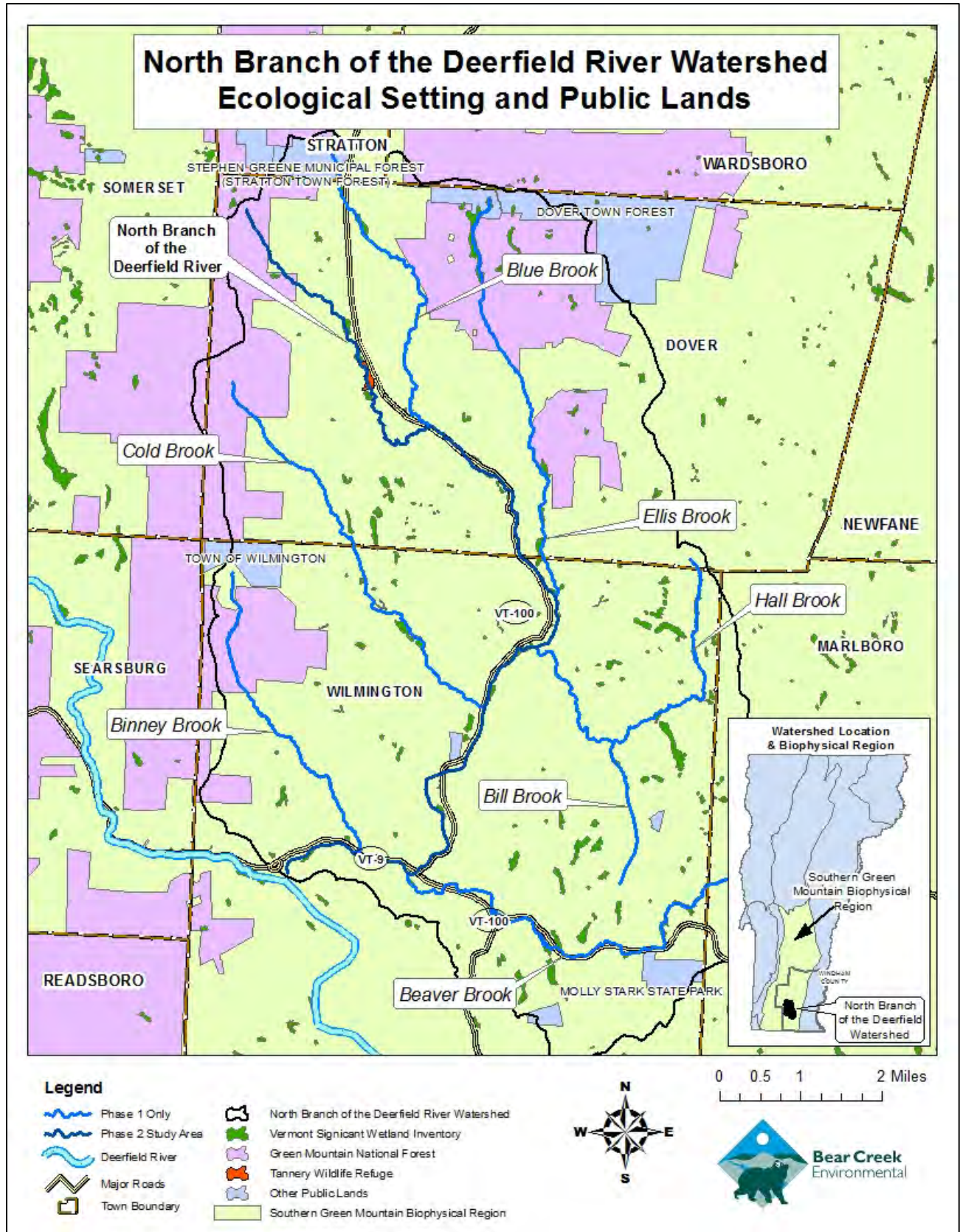


Figure 3.6. Ecological setting and public lands within the North Branch of the Deerfield watershed.

4.0 METHODS

4.1 Phase 2 Assessment

The Phase 2 assessment followed procedures specified in the Vermont Stream Geomorphic Assessment Handbook Phase 2 (Vermont Agency of Natural Resources 2005). 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.

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

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

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

4.2 Bridge & Culvert Assessment

Bridge assessments were conducted by BCE on all public and private crossings within the selected Phase 2 reaches during fall 2012. The Agency of Natural Resources Bridge and Culvert protocols (Vermont Agency of Natural Resources, 2009a) were followed. Latitude and Longitude at each of the structures was determined using a Garmin etrex GPS unit. The assessment included photo documentation of the inlet, outlet, upstream, and downstream of each of the structures.

A total of 16 stream crossings (14 bridges, 2 *culverts*) were evaluated by BCE. The Vermont Culvert Geomorphic Compatibility Screening Tool (Milone and MacBroom, Inc. 2008) was used to determine geomorphic compatibility for each bridge and culvert. Bridges are not typically screened for geomorphic compatibility in the VANR protocol because they are usually more robust and have less impact on stream channel function than culverts. Bridges also do not have potential to become perched above the water surface, because the bottom of the structure is natural substrate. Bridges in this study were screened using the geomorphic compatibility tool that was modified by BCE to exclude the slope parameter. Tables 1 through 4 in Appendix A explain how each bridge and culvert was scored using the geomorphic compatibility screening tool. The compatibility rating is based on five criteria: structure width in relation to *bankfull*

channel width, sediment continuity, slope (culvert only), river approach angle, and erosion & armoring and the ratings span the following range:

- Fully Compatible
- Mostly Compatible
- Partially Compatible
- Mostly incompatible
- Fully Incompatible

The two culverts were evaluated for Aquatic Organism Passage (AOP) using the Vermont Culvert Aquatic Organism Passage Screening Tool (Milone and MacBroom, 2009). Table 5 in Appendix A explains how each culvert was scored using the screening tool. The screening guide has the four following categories:

- Full AOP for all organisms
- Reduced AOP for all aquatic organisms
- No AOP for all aquatic organisms except adult salmonids
- No AOP for all aquatic organisms

5.0 RESULTS

5.1 Reach/Segment Descriptions

Reach and segment descriptions, including photos, and Phase 2 *Rapid Geomorphic Assessment* (RGA) and *Rapid Habitat Assessment* (RHA) results can be found in Bear Creek Environmental, 2006. Table 1 presents a summary of the data collected during the Phase 2 assessment relating to geomorphic adjustment processes. The maps on pages 1 and 2 of Appendix B show the reference and existing stream types for the North Branch of the Deerfield River. The map on page 3 of Appendix B includes the geomorphic condition for the North Branch of the Deerfield River.

Table 1. Stream Type and Channel Evolution Stage Summary North Branch of the Deerfield River Watershed							
Segment Number	Entrenchment Ratio	Width to Depth Ratio	Reference Stream Type & Dominant Bed Material	Incision Ratio	Existing Stream Type & Dominant Bed Material	Channel Evolution Stage	Active Adjustment Process
T2.01 ¹	n/a	n/a		n/a			
T2.02	1.3	21.4	B4c	3.1	F4	F-III	Aggradation Widening Planform
T2.03-A	1.4	19.7	B4c	2.2	F4	F-II	Aggradation Widening Planform
T2.03-B	5.2	20.0	C4	1.4	C4	F-III	Aggradation Widening Planform
T2.04-A	3.1	19.6	C4	1.3	C4	F-IV	Aggradation Widening Planform
T2.04-B	1.7	19.1	C4	1.4	B4c	F-II	Aggradation Widening Planform
T2.05	3.8	22.0	C4	1.7	C4	F-III	Aggradation Widening Planform
T2.06	4.3	42.3	C4	1.0	C4	F-IV	Aggradation Widening Planform
T2.07	1.1	30.0	C4	2.2	F4	F-III	Aggradation Widening Planform
T2.08-A	18.5	20.5	C4	1.7	C4	F-III	Aggradation Widening Planform
T2.08-B	1.2	18.1	C4	2.2	F4	F-III	Aggradation Widening Planform
T2.09	1.5	24.7	B4c	3.8	F4	F-III	Aggradation Widening Planform
T2.10	1.1	20.3	C3	2.3	F3	F-III	Aggradation Widening Planform
T2.11-A	1.3	22.1	C3	2.2	F3	F-III	Aggradation Widening Planform
T2.11-B ¹	n/a	n/a		n/a		n/a	
T2.12 ¹	n/a	n/a		n/a		n/a	

Table 1. Stream Type and Channel Evolution Stage Summary North Branch of the Deerfield River Watershed							
Segment Number	Entrenchment Ratio	Width to Depth Ratio	Reference Stream Type & Dominant Bed Material	Incision Ratio	Existing Stream Type & Dominant Bed Material	Channel Evolution Stage	Active Adjustment Process
T2.13-A	3.2	12.1	C4b	1.7	C4b	F-III	Aggradation Widening Planform
T2.13-B	1.7	12.2	B3	1.3	B3	F-IV	Aggradation Widening Planform
T2.13-C	1.4	20.3	B1	1.0	B1	D-IIId	Aggradation Widening Planform
T2.14-A	1.2	9.1	C3	2.3	G3	F-II	Aggradation Widening Planform
T2.14-B	2.7	12.6	C4b	1.1	C4b	F-I	None
T2.14-C	1.9	5.7	B3a	1.0	B3a	F-I	None
T2.14-D ¹	n/a	n/a		n/a		n/a	
¹ Segment not assessed. T2.01 was impounded by Harriman Reservoir. T2.11-B was impounded by beaver dams. T2.12 is the Snow Lake impoundment. T2.14-D was a stable system and there was no flowing water at time of assessment.							
Reference Ranges							
		<u>B Stream Type</u>		<u>C Stream Type</u>			
Entrenchment Ratio		1.4 – 2.2		> 2.2			
Width to Depth Ratio		< 12		< 12			
Incision Ratio		< 1.2		< 1.2			
Bold Red lettering – denotes severe adjustment process Bold Black lettering – denotes major adjustment process Black lettering (no bold) – denotes minor adjustment process Red denotes severe incision ratio (≥2.0) Blue denotes moderate incision ratio (1.4 – <2.0) Green denotes no incision to minor incision (<1.4) Orange denotes a stream type or dominant bed material type departure							

5.2 Bridge & Culvert Results

Fourteen bridges and two culverts were assessed in 2012 using the ANR protocol (2009a). Results tables, geomorphic compatibility ratings, and AOP ratings are found on pages 4 and 5 of Appendix A. Locations of the stream crossings with geomorphic compatibility and AOP ratings are found on pages 6 and 7 of Appendix A. Two bridges were determined to be “mostly compatible,” nine were “partially compatible,” and three were considered “mostly incompatible.” The bridges that were considered “mostly incompatible” all had high erosion and failed bank armoring associated with them.

The Route 100N bridge in Wilmington has a pier that splits the stream channel in two. Streambed scour along the pier may lead to the undermining of the structure. As seen in Figure 5.1, the bridge is causing upstream *deposition* and is poorly aligned in relation to the stream channel.



Figure 5.1. The Route 100N bridge in Wilmington is poorly aligned and is causing geomorphic instability.

The Higley Hill Road Bridge in Wilmington also has a pier that splits the stream channel in two. One side is filling up with deposited sediment and is blocking lower flows (Figure 5.2). A deep scour *pool* has formed around the base of the pier that may lead to undermining of the structure. Figure 5.3 shows that the Route 100 bridge in Dover is poorly aligned in relation to stream flow and is causing sediment to deposit within the structure.



Figure 5.2. The stream channel is split by a pier under the Higley Hill Road bridge. Sediment is filling one side and blocking flow.



Figure 5.3. The Route 100 bridge in Dover (ID: 200013005813042) is poorly aligned and causing deposition.

Both of the culverts that were assessed in 2012 were identified as high priority for replacement/retrofit and are included in Section 6.0 (Project Development) of this Plan. The Handle Road culvert in Dover is perched at least one foot above the water surface at the downstream end (See Figure 5.4). This culvert was found to be “mostly incompatible” with the lowest AOP rating, “No AOP including adult salmonids.” The North Access Road culvert consists of two culverts side by side. These culverts are both slightly perched above the water surface at the downstream end. The culverts are causing upstream deposition (Figure 5.5), which may lead to future blockage problems. The North Access Road culvert was determined to be “partially compatible” with an AOP rating of “No AOP except adult salmonids.”



Figure 5.4. The Handle Road culvert is perched. **Figure 5.5.** North Access Rd. culverts are causing deposition.

6.0 Stressor, Departure, and Sensitivity Analysis

Stressor, departure, and sensitivity maps are presented on pages 4 through 8 of Appendix B as a means of displaying the effects of all significant physical processes occurring within the North Branch of the Deerfield River Watershed that were observed during the Phase 1 and Phase 2 Stream Geomorphic Assessments. These maps also provide an indication of the degree to which the channel *adjustment processes* within the watershed have been altered at both the watershed scale and the reach scale. The analysis of existing and historic departures from equilibrium conditions along a stream network allows for the prediction of future alterations within the watershed. This is helpful in developing and prioritizing potential protection and restoration projects.

6.1 Stressor Identification

6.1.1 Hydrologic Regime Stressors

The hydrologic regime is the timing, volume, and duration of flow events throughout the year and over time and is characterized by the input of precipitation and manipulation of the hydrology at the watershed scale. When the hydrologic regime has been significantly altered, stream channels will respond by undergoing a series of channel adjustments.

The land use within the watershed plays a role in the hydrology of the receiving waters. The percentage of urban and cropland development within the watershed are factors which change a watershed's response to precipitation. The most common effects of urban and cropland development is increasing peak discharges and runoff by reducing infiltration and travel time (United States Department of Agriculture, 1986). The dominant watershed land cover/land use within the North Branch of the Deerfield River Watershed is forest. The impact rating for watershed land cover/land use was low (between 7% and 15% is crop and/or urban). Analysis of hydric soils located where current land uses are agricultural or urban indicates some loss of wetland attenuation (Appendix B, page 4).

The North Branch of the Deerfield River Watershed has an extensive network of roads as shown in Appendix B, page 4. Roads can contribute significantly to increased flows within a river resulting both from increased runoff and stormwater ditching. According to Foreman and Alexander (1998), increased peak flows in streams may be evident at road densities of 3.2 miles/ square mile. Subwatersheds with road densities of greater than 3.2 miles/ square mile account for about 42 percent of the North Branch of the Deerfield River Watershed. The highest road density within the watershed is found in subwatershed of Reach T2.10-S1.01, which is the most downstream reach on Blue Brook.

6.1.2 Channel Modifiers

Channel straightening, floodplain encroachment, and *berms* and roads can increase the slope of a channel resulting in increased stream power. Impacts that cause increases in

stream power (shown in red or orange on page 5 of Appendix B) can initiate streambed erosion resulting in *incision*. Much of the North Branch flows along VT Route 100 and the potential of channel modification from adjacent roads is prevalent throughout the watershed. The most extensive areas of channel straightening and floodplain encroachment (both development and adjacent berms and roads) along the North Branch of the Deerfield River are in the downstream reaches in Dover T2.09 and T2.10, segments adjacent to Mount Snow Ski Area, and in Wilmington where river corridor development is extensive. All reaches downstream of T2.11, except for Reach T2.06, have areas of channel straightening to accommodate the placement of roads. The extensive areas with increases in stream power due to channel and floodplain alteration explain the channel adjustment that is occurring within the watershed.

Grade controls (waterfalls and ledge) and natural and manmade dams and constrictions (such bridges and culverts) constrict flows or raise the bed elevation. Backwater conditions and sediment deposition typically reduce channel slope and stream power (Vermont Agency of Natural Resources, 2010a). Localized areas where slope decreases are expected in the North Branch of the Deerfield River Watershed are shown in blue and green in Appendix B, page 5.

6.1.3 Boundary Conditions and Riparian Modifiers

The resistance of the channel boundary materials is important for understanding the sensitivity of a channel and for predicting when a channel will undergo adjustment from stressors in the watershed. There are a number of factors that can result in decreased boundary condition. One of the most important factors is the quality of the riparian buffer. Riparian buffers provide many benefits including protecting and enhancing water quality, providing fish and wildlife habitat, providing streamside shading, and providing root structure to prevent bank erosion. Woody vegetation is essential for holding the bank soils to provide resistance to stream bank erosion. There are many locations along the North Branch of the Deerfield River where there is little or no buffer as defined by buffers less than 25 feet in width (Appendix B, page 6). Most of these areas are in close proximity to roads or developed areas and are not suitable for buffer plantings. In segment/reach T2.04-A and T2.05, there are areas along agricultural fields that may be suitable for planting. Stream banks which lack a high quality riparian buffer are at a significantly higher risk of experiencing high rates of lateral erosion.

Parameters which are indicative of a decrease in boundary condition are shown in orange and purple on page 6 of Appendix B. While bank armoring may temporarily increase the boundary condition, it is indicative of where the stream power has resulted in bank erosion or widening of the channel. Extensive bank armoring may increase the stream power, resulting in downstream bank erosion. Areas where woody debris, bed substrate, and plant material were removed from the channel also result in decreased boundary condition.

Important factors that result in an increase in boundary condition are included on page 6 of Appendix B with aqua colored symbols. Natural and man-made grade controls increase the resistance of the bed to erosion. There were several locations where natural grade controls (ledge) are present in T2.08-A, T2.09, T2.13-A, and T2.13-C. The cohesiveness of the lower bank materials is another factor that is considered in evaluating boundary resistance. Cohesive bank material can increase the boundary condition. All reaches/segments that were assessed for Phase 2 did not have cohesive material on the lower bank.

6.2 Departure Analysis

River corridor restoration and protection projects that are successful depend on a thorough understanding of the sources, volumes, and attenuation of flood flows and sediment loads within the stream network. If increased loads are transported through the network to a sensitive reach, where conflicts with human investments are creating a management expectation, the restoration project should be designed to accommodate the increased sediment load or find a way to attenuate the loads upstream. Modifications in watershed inputs in the form of peak flows or increased sediment can result in an imbalance of stream power and sediment in the channel. Changes in the shape of the channel may also lead to disequilibrium. Large channel adjustments, such as severe erosion and excessive deposition, are a result of this imbalance and often continue until the channel reaches a state of equilibrium (Vermont Agency of Natural Resources, 2010a).

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

Reference and existing sediment regime maps have been prepared to show departure from reference conditions due to human alterations (Appendix B, page 7). In the reference condition, streams use available floodplain access as a means to store sediment within the watershed. Ten out of the 19 fully assessed reaches/segments of the Phase 2 study area have a reference sediment regime of *Coarse Equilibrium & Fine Deposition*. These channels are unconfined on at least one side and they transport and deposit sediment in equilibrium, where the stream power is balanced by the sediment load, sediment size, and channel boundary resistance. The remaining nine reaches/segments have *Transport* as their reference sediment regime. These *Transport* channels are located throughout the watershed. *Transport* channels are steep, dominated by bedrock and boulder/cobble substrates, and are typically in confined valleys. Transport channels do not contribute appreciable quantities of sediments to downstream reaches (Vermont Agency of Natural Resources, 2010a). The valley walls of these channels are confining with limited sediment storage capacity due to both channel slope and entrenchment (Vermont Agency of Natural Resources, 2010a).

Changes in hydrology (such as development and agriculture within the riparian corridor) and sediment storage within the watershed have altered the reference sediment regime types for

some reach segments. All departures were derived from the DMS according to the sediment regime criteria established by the Vermont Agency of Natural Resources (2010a). Existing sediment regimes have not been established for reaches that were not assessed during the Phase 2 Stream Geomorphic Assessment. Four reaches/segments that were *Coarse Equilibrium & Fine Deposition* by reference have been converted to *Fine Source and Transport & Coarse Deposition* sediment regimes based on the Phase 2 Stream Geomorphic Assessment data (Appendix B, page 7). This means that most fine sediment entering the stream is transported through without being deposited as a result of channel incision and reduced floodplain access. Additionally, coarse sediment storage is increased due to increased load along with lower transport capacity. Four reaches/segments that were *Transport* by reference were converted to *Confined Source and Transport*. These channels have confining valley walls with limited sediment storage capacity due to both channel slope and entrenchment (Vermont Agency of Natural Resources, 2010a). Channel management practices such as straightening and encroachment have resulted in a change in sediment regime. The remaining five reaches/segments that were *Coarse Equilibrium and Fine Deposition* by reference were also converted to *Confined Source and Transport*. While their valleys are still unconfined, they have experienced channel and floodplain management practices which have resulted in channel incision and loss of floodplain access. Since the channel can no longer access its floodplain, sediment storage capacity has been diminished and the reaches are acting more as transport reaches than sediment storage reaches.

The sediment regime for the North Branch of the Deerfield River watershed has been altered by reduced floodplain access, increased stream power, reduced boundary resistance, and lateral constraints, such as roads, at various locations throughout the stream network. Watersheds which have lost attenuation or sediment storage areas due to human related constraints are generally more sensitive to erosion hazards, transport greater quantities of sediment and nutrients to receiving waters, and lack the sediment storage and distribution processes that create and maintain habitat (Vermont Agency of Natural Resources, 2010a).

6.3 Sensitivity Analysis

Sensitivity ratings were assigned using the River Corridor Planning Guide Management Program (Vermont Agency of Natural Resources, 2010a). Stream sensitivity refers to the likelihood that a stream will respond to a watershed or local disturbance or stressor. Human activities such as: floodplain encroachment, channel straightening or armoring, changes in sediment or flow inputs, and/or disturbance of riparian vegetation may alter the natural adjustment rate of the channel. Streams that are actively adjusting through a lowering of the bed (*degradation*) or building up of the bed through sediment deposition (*aggradation*) are likely to have a heightened sensitivity (Vermont Agency of Natural Resources, 2009b). Stream sensitivity is assigned based on the existing stream type and condition. For a particular stream type, a segment in “reference” or “good” condition has a lower sensitivity than a reach in “fair” condition. The highest sensitivity is assigned for segments in “poor” condition and reaches which have undergone a stream type departure.

There are many variables that are contributing to the sensitivity of the reaches in the North Branch of the Deerfield River watershed. Some reaches/segments contain bedrock grade controls, which decreases the stream's sensitivity to vertical adjustment. In many reaches, the lack of bedrock decreases the resistance to lateral and vertical adjustments; thereby, making the channel more sensitive. Additionally, bank vegetation and roots which hold the soil are lacking especially in areas where there is little or no buffer. Reaches that are lacking high quality riparian vegetation are more sensitive to channel adjustment.

The location and slope of a stream also affects its morphology and sensitivity. Streams that are transporting sediment through the channel are less sensitive than streams that are storing and responding to sediment. Flow regime and floodplain constrictions may be affecting the sensitivity of the North Branch of the Deerfield River. Changes in land use and land cover that increase impervious cover, peak discharges, and/or the frequency of high flows will heighten a stream's sensitivity to change and adjustment. Confinement becomes a significant sensitivity concern when structures such as roads, railroads, and berms significantly change the confinement ratio, reduce or restrict a stream's access to floodplain, and result in higher stream power during flood stage.

Page 8 in Appendix B is a map presenting the stream sensitivity, generalized according to stream type and condition for each reach/segment assessed during the Phase 2 assessment on the North Branch of the Deerfield River. Eight reaches/segments received a sensitivity of "extreme" due to their condition and departure of stream type from reference conditions. All of these reaches/segments have undergone severe incision due to floodplain encroachment and/or channel alterations, resulting in stream type departures and are in "fair" geomorphic condition with the exception of reach T2.10, which is in "poor" condition. Reference stream types are either "Bc" or "C," while the existing stream type for all of these highly sensitive reaches/segments is "F" except for one segment (T2.14-A) that has an existing stream type of "G."

Six reaches/segments resulted in a "very high" sensitivity. Their "fair" geomorphic condition and stream type of "C" have contributed to this sensitivity rating. Although segment T2.04-B is in "fair" geomorphic condition, its existing stream type is "Bc," resulting in a "high" sensitivity. The only other segment with a "high" sensitivity is T2.14-B, which is a "Cb" stream in "reference" condition. Two cobble dominated reaches/segments (T2.13-B and T2.14-C) are in "good" and "reference" condition, respectively, and both have an existing stream type of "B." These segments are more stable and in better condition than most of the other segments, resulting in a "moderate" sensitivity rating. The only segment with a "very low" sensitivity is T2.13-C, which is a bedrock dominated segment in "good" geomorphic condition with a "B" stream type. Its sensitivity is "very low" due to the stability provided by the bedrock in the channel.

7.0 PROJECT IDENTIFICATION AND IMPLEMENTATION

7.1 Watershed Level Opportunities

On the watershed level, the implementation of fluvial erosion hazard zones is recommended to reduce conflicts regarding land use and to save money spent on flood damage and river maintenance. River corridors, defined through VTANR Stream Geomorphic Assessment (2008a), are intended to provide landowners, land use planners, and river managers with a meander belt width which would accommodate the meanders and slope of a balanced or equilibrium channel, which when achieved, would serve to maximize channel stability and minimize fluvial erosion hazards. Draft Fluvial Erosion Hazards Zones for the North Branch of the Deerfield River watershed in Dover and Wilmington, Vermont were developed by Shannon Pytlik, River Scientist with the Vermont Department of Environmental Conservation, River Management Program. These zones are included on project maps in Appendix C.

7.2 Site Level Opportunities

Site specific projects were identified using the criteria outlined by the VANR in Chapter 6 – Preliminary Identification and Prioritization (Vermont Agency of Natural Resources 2010a). This planning guide is intended to aid in the development of projects that protect and restore river equilibrium. Project maps and tables (Appendix C, pages 1 through 14) have been developed for the North Branch of the Deerfield River watershed. These maps were created using indexed data from the Phase 2 stream geomorphic assessments along with existing data available from the Vermont Center for Geographic Information.

A total of 20 projects were identified by BCE to promote the restoration or protection of channel stability and aquatic habitat in the North Branch of the Deerfield River watershed. The projects are broken down by category as follows: 19 passive restoration (streamside plantings and corridor easements); 2 stormwater improvement projects; and 10 active restoration projects (two investigations into old bridge abutment removals, two berm removals, two riparian restorations, two culvert replacements, , and the restoration of a natural channel around Snow Lake. Additional information from the Phase 2 stream geomorphic assessment and bridge assessments could be used to inform the Towns of Wilmington and Dover of which bridges are contributing to localized instability. The projects include:

Map #1, Table #1

- **Active Restoration** by reducing the encroachment of existing rip rap in T2.01 (Project #1)
- **Active Restoration** by investigating the removal of an old abutment in T2.02 (Project #2)

Map #2, Table #2

- **Passive Restoration** by planting trees along the bank adjacent to the agricultural fields in T2.03-B and T2.04-A (Project #1)

- **Passive Restoration** by protecting the river corridor through an easement in T2.04-A (Project #2)
- **Passive Restoration** by planting trees along the agricultural fields in areas where buffers are less than 25 feet wide in T2.04-A (Project #3)
- **Passive Restoration** by planting trees along agricultural fields in areas where buffers are less than 25 feet wide in upstream areas of T2.04-A (Project #4)

Map #3, Table #3

- **Passive Restoration** by protecting the river corridor through an easement in T2.05 (Project #1)
- **Passive Restoration** by planting trees in areas where buffers are less than 25 feet wide in T2.05 (Project #2)

Map #4, Table #4

- **Passive Restoration** by protecting the river corridor through an easement in T2.06 and T2.07 (Project #1)
- **Active Restoration** by investigating the removal of an old abutment in T2.07 (Project #2)
- **Passive Restoration** by protecting the river corridor through an easement in T2.07 and T2.08-A on the main stem and the lower section of a tributary (Project #3)
- **Active Restoration** by removing a berm that restricts floodplain access in T2.08-B (Project #4)

Map #5, Table #5

- **Stormwater Management** of developed area in West Dover (Project #1)
- **Passive Restoration** by protecting the river corridor through an easement (Project #2)

Map #6, Table #6

- **Active Restoration** by reestablishing a natural stream channel around Snow Lake (Project #1)
- **Active Restoration** by restoring the riparian area along the channel in T2.13-A to improve floodplain and stormwater management (Project #2)
- **Active Restoration** by replacing the Handle Road culvert (Project #3)
- **Stormwater Management** of ski area parking lots (Project #4)

Map #7, Table #7

- **Active Restoration** by restoring the riparian area along the channel in T2.14-A to improve floodplain and stormwater management (Project #1)
- **Active Restoration** by replacing the North Access Road culvert (Project #2)

7.3 Outreach

Bear Creek Environmental, LLC and project partners provided outreach to private landowners and community members about the river corridor plan and potential projects at two public meetings. The first public meeting was held at the Wilmington Town offices on May 22, 2013. Approximately fifteen individuals attended the meeting. Eight people attended the second public at the Dover Town Hal on June 5, 2013.

Project development packets were prepared for the five top projects selected by the steering committee. Landowner outreach took place during June and July 2013 to gage interest of riparian landowners.

7.4 Next Steps

There are many opportunities available to work towards restoring the North Branch of the Deerfield River to stable conditions. Preliminary reach level and site level projects have been identified and will form the bases for future project development. The following are recommendations for next steps.

1. Acquire funding and hire contractors (river scientists and engineers) to prepare project design and implementation strategies for selected high priority projects (refer to Section 6.1).
2. Obtain funding and perform Phase 2 assessment of tributaries to the North Branch of the Deerfield River and develop FEH zones. High priority areas for additional Phase 2 assessment work include: Beaver Brook along Route 9, the lower end of Ellis Brook, Cold Brook, and Binney Brook.

For additional information about river restoration and protection opportunities within the North Branch of the Deerfield River watershed please contact:

John Bennett, Senior Planner
Windham Regional Commission
139 Main Street, Suite 505
Brattleboro, VT 05301
johnbenn@sover.net
(802) 257-4547 ext. 110



8.0 ACRONYMS AND GLOSSARY OF TERMS

List of Acronyms

BCE – Bear Creek Environmental, LLC
CREP – Conservation Reserve Enhancement Program
CRWC – Connecticut River Watershed Council
DEC – Vermont Department of Environmental Conservation
EQIP – Environmental Quality Incentives Program
ERP – Ecosystem Restoration Program
FEH – Fluvial Erosion Hazard Zone
GIS – Geographic Information System
NRCS – Natural Resources Conservation Service
QA/QC – Quality Assurance/Quality Control
RCE – ANR River Corridor Easement Program
RHA - Rapid Habitat Assessment
RGA - Rapid Geomorphic Assessment
RMCP – River Corridor Management Plan
SGA – Stream Geomorphic Assessment
SGAT – Stream Geomorphic Assessment Tool
TFS – Trees for Streams
TSI – Tropical Storm Irene
USDA – United States Department of Agriculture
USFWS – United States Fish & Wildlife Service
USGS – United States Geological Survey
VANR – Vermont Agency of Natural Resources
VCF – Vermont Community Foundation
VCGI – Vermont Center for Geographic Information
WHIP – Wildlife Habitat Incentives Program
WRC – Windham Regional Commission
WRP – Wetland Reserve Program

Glossary of Terms

Adapted from:

Restoration Terms, by Craig Fischenich, February, 2000, USAE Research and Development Center, Environmental Laboratory, 3909 Halls Ferry Rd., Vicksburg, MS 39180

And

Vermont Stream Geomorphic Assessment Handbook, Appendix Q, 2009, VT Agency of Natural Resources, Waterbury, VT.

http://www.vtwaterquality.org/rivers/docs/assessmenthandbooks/rv_apxgglossary.pdf

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

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

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

Alluvial Soils – Soil deposits from rivers.

Alluvium – A general term for detrital deposits made by streams on riverbeds, floodplains, and alluvial fans.

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

Bank Stability – The ability of a stream bank to counteract erosion or gravity forces.

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

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

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

Bar – An accumulation of alluvium (usually gravel or sand) caused by a decrease in sediment transport capacity on the inside of meander bends or in the center of an over wide channel.

Bedform – Type of channel morphology (e.g., riffle-pool, plane bed, cascade, dune-ripple).

Berms – Mounds of dirt, earth, gravel or other fill built parallel to the stream banks designed to keep flood flows from entering the adjacent floodplain.

Bifurcated Channel – A river channel that has split into two branches as a result of planform adjustment (i.e. split flow due to island).

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

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

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

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

Delta Bar – A deposit of sediment where a tributary enters the main stem of a river.

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

Diagonal Bar – Type of depositional feature perpendicular to the bank that is formed from excess sedimentation and within the channel and from the development of steep riffles.

Drainage Basin – The total area of land from which water drains into a specific river.

Dredging – Removing material (usually sediments) from wetlands or waterways, usually to make them deeper or wider.

Entrenchment Ratio – A ratio that shows the extent of floodplain access the channel has or its vertical containment. The ratio is calculated by dividing the current floodprone width by the bankfull width.

Erosion – The wearing away of rock or soil by the gradual detachment of soil or rock fragments by water, wind, ice, and other mechanical, chemical, or biological forces.

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

Floodprone Width – The wetted width of the channel when the water level is twice the maximum bankfull depth. For most channels this is associated with less than a 50 year return period (Rosgen, 1996).

Fluvial Geomorphology – The physics of flowing water, sediments, and other products of watersheds in relation to various land forms.

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

Grade Control - A fixed feature on the streambed that controls the bed elevation at that point, effectively fixing the bed elevation from potential incision; typically bedrock, dams or culverts.

Gradient – Vertical drop per unit of horizontal distance.

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

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

Head Cut – Sudden change in elevation or knickpoint at the leading edge of a gully

Incised River – A river that erodes its channel by the process of degradation to a lower base level than existed previously or is consistent with the current hydrology.

Incision Ratio – A ratio that shows the extent or severity of erosion of the streambed. The ratio is calculated by dividing the recently abandoned floodplain elevation by the current bankfull elevation.

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

Lacustrine Soils- Soil deposits from lakes.

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

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

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

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

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

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

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

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

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

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

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

Rapid Geomorphic Assessment – Uses direct observations and mapping to evaluate stream geomorphic condition and channel adjustment processes.

Rapid Habitat Assessment – Uses direct observations and mapping to understand habitat condition.

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

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

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

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

Riparian – Of, relating to, or situated on the banks of a river.

Riparian Buffer – The width of naturally vegetated land adjacent to the stream between the top of the bank and the edge of other land-uses. A buffer is largely undisturbed and consists of the trees, shrubs, groundcover plants, duff layer, and naturally uneven ground surface.

Riparian Corridor – Lands defined by the lateral extent of a stream’s meanders necessary to maintain a stable stream dimension, pattern, profile, and sediment regime.

Segment – A relatively homogeneous section of stream contained within a reach that has the same reference stream characteristics but is distinct from other segments in the reach.

Sensitivity – The valley, floodplain and/or channel condition’s likelihood to change due to natural causes and/or anticipated human activity.

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

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

Steep Riffle – Associated with aggradation where sediment has dropped out to form a steep face of sediment on the downstream side.

Surficial Sediment/Geology – The geology of the sediment that lies on top of bedrock, including types of soils such as alluvium, glacial till, etc.

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

Tributary Rejuvenation – As the bed of the main stem is lowered, head cuts (incision) begin at the mouth of the tributary and move upstream.

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

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APPENDIX A

Bridge & Culvert Assessment Data

Table 1. Scoring Table (Vermont Culvert Geomorphic Compatibility Screen Tool, adapted by BCE for bridges)				
Score	% Bankfull Width	Sediment Continuity	Approach Angle	Erosion and Armoring
5	%BFW \geq 120	No upstream deposition or downstream bed scour	Naturally Straight	No erosion or armoring
4	$100 \leq$ %BFW $<$ 120	Either upstream deposition or downstream bed scour, without upstream deposits taller than 0.5 bankfull height or high downstream banks	n/a	No erosion and intact armoring, or low upstream or downstream erosion without armoring
3	$75 \leq$ %BFW $<$ 100	Either upstream deposition or downstream bed scour, with either upstream deposits taller than 0.5 bankfull height or high downstream banks	Mild bend	Low upstream or downstream erosion with armoring
2	$50 \leq$ %BFW $<$ 75	Both upstream deposition and downstream bed scour, without upstream deposits taller than 0.5 bankfull height or high downstream banks	Channelized Straight	Low upstream and downstream erosion
1	$30 \leq$ %BFW $<$ 50	Both upstream deposition and downstream bed scour, with upstream deposits taller than 0.5 bankfull height or high downstream banks	n/a	Severe upstream or downstream erosion
0	%BFW $<$ 30	Both upstream deposition and downstream bed scour, with upstream deposits taller than 0.5 bankfull height and high downstream banks	Sharp Bend	Severe upstream and downstream erosion, or failing armoring upstream or downstream

Table 2. Compatibility Rating Results (Vermont Culvert Geomorphic Compatibility Screen Tool, adapted by BCE for bridges)			
Category Name	Screen Score	Threshold Conditions	Description of Structure-channel Geomorphic Compatibility
Fully Compatible	$16 < GC \leq 20$	n/a	Structure fully compatible with natural channel form and process. There is a low risk of failure. No replacement anticipated over the lifetime of the structure. A similar structure is recommended when replacement is needed.
Mostly Compatible	$12 < GC \leq 16$	n/a	Structure mostly compatible with current channel form and process. There is a low risk of failure. No replacement anticipated over the lifetime of the structure. Minor design adjustments recommended when replacement is needed to make fully compatible.
Partially Compatible	$8 < GC \leq 12$	n/a	Structure compatible with either current form or process, but not both. Compatibility likely short term. There is a moderate risk of structure failure and replacement may be needed. Re-design suggested to improve geomorphic compatibility.
Mostly Incompatible	$4 < GC \leq 8$	% Bankfull Width + Approach Angle scores ≤ 2	Structure mostly incompatible with current form and process, with a moderate to high risk of structure failure. Re-design and replacement planning should be initiated to improve geomorphic compatibility.
Fully Incompatible	$0 \leq GC \leq 4$	% Bankfull Width + Approach Angle scores ≤ 2 AND Sediment Continuity + Erosion and Armoring scores ≤ 2	Structure fully incompatible with channel and high risk of failure. Re-design and replacement should be performed as soon as possible to improve geomorphic compatibility.

Table 3. Scoring Table
Vermont Culvert Geomorphic Compatibility Screen Tool (Milone & MacBroom, 2008)

Score	% Bankfull Width	Sediment Continuity	Slope	Approach Angle	Erosion and Armoring
5	%BFW \geq 120	No upstream deposition or downstream bed scour	Structure slope equal to channel slope, and no break in valley slope	Naturally Straight	No erosion or armoring
4	$100 \leq$ %BFW < 120	Either upstream deposition or downstream bed scour, without upstream deposits taller than 0.5 bankfull height or high downstream banks	n/a	n/a	No erosion and intact armoring, or low upstream or downstream erosion without armoring
3	$75 \leq$ %BFW < 100	Either upstream deposition or downstream bed scour, with either upstream deposits taller than 0.5 bankfull height or high downstream banks	Structure slope equal channel slope, with local break in valley slope	Mild bend	Low upstream or downstream erosion with armoring
2	$50 \leq$ %BFW < 75	Both upstream deposition and downstream bed scour, without upstream deposits taller than 0.5 bankfull height or high downstream banks	Structure slope higher or lower than channel slope, and no break in valley slope	Channelized Straight	Low upstream and downstream erosion
1	$30 \leq$ %BFW < 50	Both upstream deposition and downstream bed scour, with upstream deposits taller than 0.5 bankfull height or high downstream banks	n/a	n/a	Severe upstream or downstream erosion
0	%BFW < 30	Both upstream deposition and downstream bed scour, with upstream deposits taller than 0.5 bankfull height and high downstream banks	Structure slope higher or lower than channel slope, with local break in valley slope	Sharp Bend	Severe upstream and downstream erosion, or failing armoring upstream or downstream

Table 4. Geomorphic Compatibility Rating Results
Vermont Culvert Geomorphic Compatibility Screen Tool (Milone & MacBroom, 2008)

Category Name	Screen Score	Threshold Conditions	Description of Structure-channel Geomorphic Compatibility
Fully Compatible	$20 < GC \leq 25$	n/a	Structure fully compatible with natural channel form and process. There is a low risk of failure. No replacement anticipated over the lifetime of the structure. A similar structure is recommended when replacement is needed.
Mostly Compatible	$15 < GC \leq 20$	n/a	Structure mostly compatible with current channel form and process. There is a low risk of failure. No replacement anticipated over the lifetime of the structure. Minor design adjustments recommended when replacement is needed to make fully compatible.
Partially Compatible	$10 < GC \leq 15$	n/a	Structure compatible with either current form or process, but not both. Compatibility likely short term. There is a moderate risk of structure failure and replacement may be needed. Re-design suggested to improve geomorphic compatibility.
Mostly Incompatible	$5 < GC \leq 10$	% Bankfull Width + Approach Angle scores ≤ 2	Structure mostly incompatible with current form and process, with a moderate to high risk of structure failure. Re-design and replacement planning should be initiated to improve geomorphic compatibility.
Fully Incompatible	$0 \leq GC \leq 5$	% Bankfull Width + Approach Angle scores ≤ 2 AND Sediment Continuity + Erosion and Armoring scores ≤ 2	Structure fully incompatible with channel and high risk of failure. Re-design and replacement should be performed as soon as possible to improve geomorphic compatibility.

Table 5. Aquatic Organism Passage (AOP) Coarse Screen Tool
(Milone & MacBroom, 2009)

VT Aquatic Organism Passage Coarse Screen	Full AOP	Reduced AOP	No AOP			
Updated 2/25/2008	for all aquatic organisms	for all aquatic organisms	for all aquatic organisms except adult salmonids		for all aquatic organisms including adult salmonids	
AOP Function Variables / Values	Green (if all are true)	Gray (if any are true)	Orange		Red	
Culvert outlet invert type	at grade OR backwatered	cascade	free fall AND		free fall AND	
Outlet drop (ft)	= 0		> 0 , < 1 ft OR		≥ 1 ft OR	
Downstream pool present			= yes	(= yes AND	= no OR	(= yes AND
Downstream pool entrance depth / outlet drop			n/m	≥ 1)	n/a	< 1) OR
Water depth in culvert at outlet (ft)					< 0.3 ft	
Number of culverts at crossing	1	> 1				
Structure opening partially obstructed	= none	≠ none				
Sediment throughout structure	yes	no				

Notes:

Assessment completed during low flows

Outlet drop = invert of structure to water surface

Pool present variable is used alone if pool depths are not measured

n/m = not measured

n/a = not applicable

**Table 6. North Branch of the Deerfield River Bridge Assessment (2012)
Geomorphic Compatibility**

Reach/ Segment Number	Town	Road Name	Structure ID ¹	Percent Bankfull Channel Width ²		Phase 2 Notes	Scoring					Category
				Constriction	Span ³		% Bankfull Width ⁵	Sediment Continuity	Approach Angle	Erosion & Armoring	Total Score	
T2.03-A	Wilmington	Route 9	200010003113222	80	87	Deposition above and below. Scour above and below.	3	1	² Channelized Straight	4	10	Partially Compatible
T2.04-A	Wilmington	N/A	N/A	89	92 ⁴	Bridge not used anymore. Beaver dam ~ 600 feet downstream of structure. River impounded at location of bridge.	3	5	² Channelized Straight	5	15	Mostly Compatible
T2.04-A	Wilmington	Route 100N	200013005113222	93	159	Deposition above and below. Scour above and below. Poorly aligned. Pier splits channel in two.	3	2	² Channelized Straight	0	7	Mostly Incompatible
T2.05	Wilmington	Higley Hill Road	101322001613221	113	221	Deposition above and below. Scour above and below. Poorly aligned. Pier splits channel in two.	4	2	² Channelized Straight	0	8	Mostly Incompatible
T2.07	Wilmington	East Dover Road	200106001913222	142	230	Deposition above and below. Scour above. Pier splits channel in two.	5	3	³ Mild Bend	1	12	Partially Compatible
T2.08-A	Wilmington	N/A	N/A	144	160 ⁴	Bridge for golf course path. No problems.	5	4	² Channelized Straight	0	11	Partially Compatible
T2.10	Dover	Route 100	200013005613042	148	222	Deposition below. Poorly aligned.	5	5	³ Mild Bend	2	15	Mostly Compatible
T2.10	Dover	Cross Town Road	101304002913041	93	107	Scour above and below. Poorly aligned.	3	4	² Channelized Straight	0	9	Partially Compatible
T2.10	Dover	Route 100	200013005813042	74	162	Deposition inside structure. Scour above and below. Poorly aligned.	2	2	² Channelized Straight	0	6	Mostly Incompatible
T2.10	Dover	N/A	N/A	148	201 ⁴	Bridge for bike path. Deposition below.	5	5	² Channelized Straight	0	12	Partially Compatible
T2.11-A	Dover	Route 100	200013005913042	95	130	Scour above.	3	4	³ Mild Bend	0	10	Partially Compatible
T2.11-A	Dover	Kingswood Road	N/A	71	78 ⁴	Scour above. This is an arch.	2	2	⁵ Naturally Straight	1	10	Partially Compatible
T2.11-A	Dover	Tannery Road	200222003013042	67	193	Deposition above and below.	2	4	³ Mild Bend	0	9	Partially Compatible
T2.13-A	Dover	N/A	N/A	93	231 ⁴	Private foot bridge. Deposition above and below.	3	3	⁵ Naturally Straight	0	11	Partially Compatible

¹The structure ID is the identification number provided by the 2010 "TransStructures_TRANSTRUC" shapefile from the Vermont Center for Geographic Information, unless no number was available.

²Percent Bankfull Channel Width percentages are calculated based on the reference channel width for each reach. The constriction percentage is calculated by dividing the present constriction width by the reference channel width. The span percentage is calculated by dividing the bridge span by the reference channel width.

³The bridge span used for this calculation is based on the bridge span provided by the 2010 "TransStructures_TRANSTRUC" shapefile from the Vermont Center for Geographic Information, unless otherwise noted.

⁴The bridge spans for the unused bridge (T2.04-A), the golf course bridge (T2.08-A), the bike path bridge (T2.10), the Kingswood Road arch (T2.11-A), and the private footbridge (T2.13-A) were measured in the field.

⁵The % bankfull width is based on the constriction calculation.

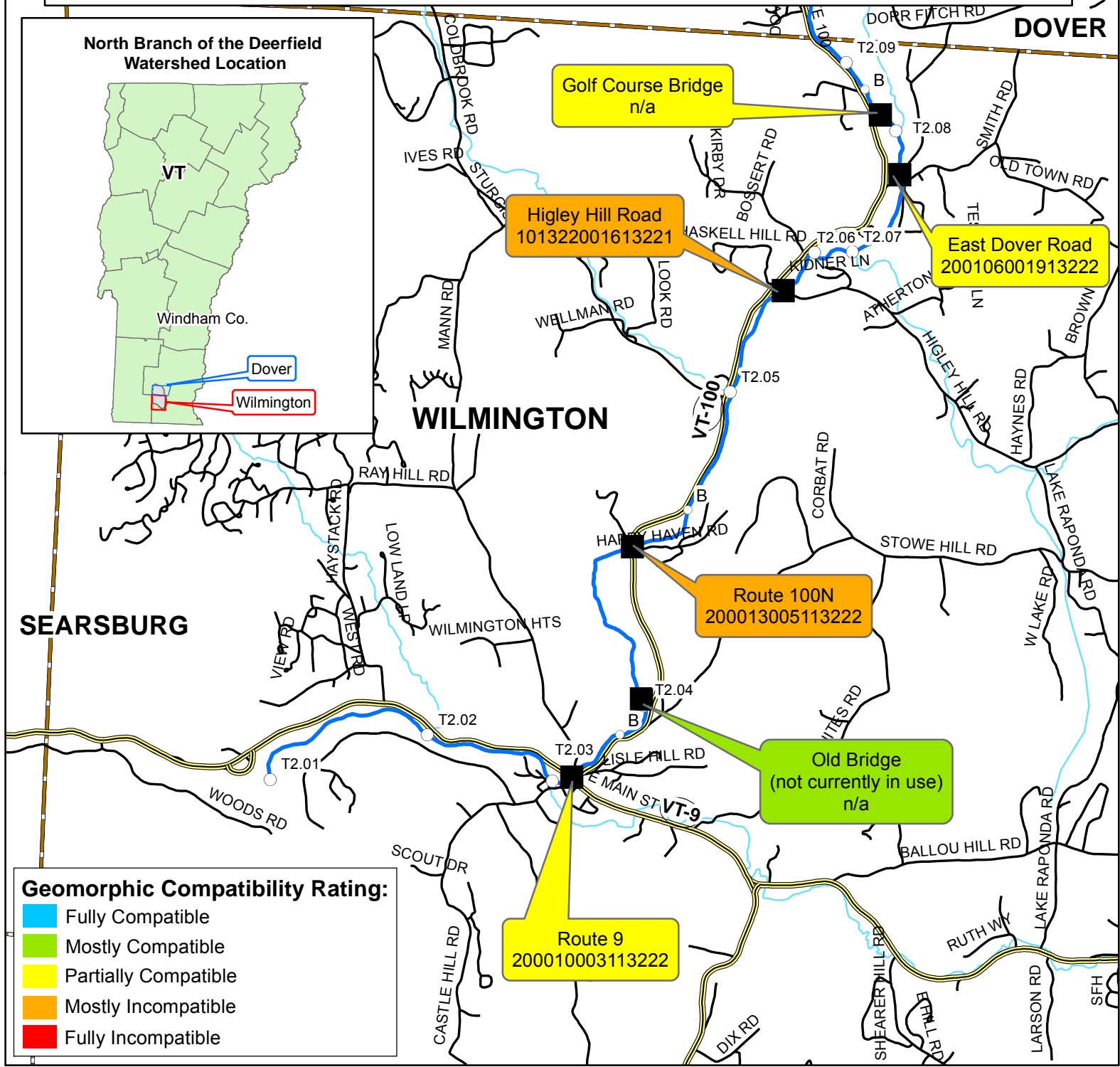
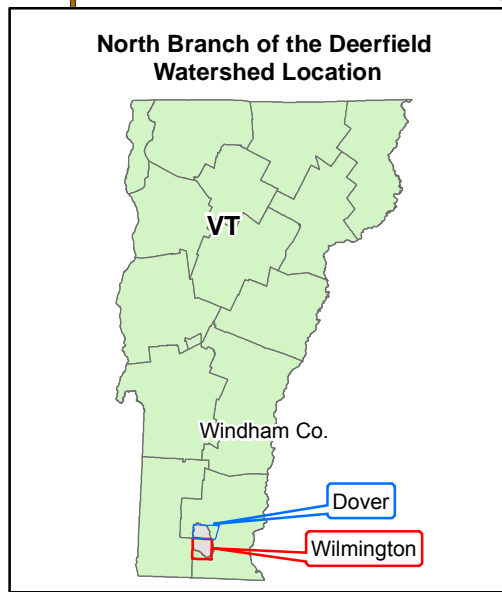
**Table 7. North Branch of the Deerfield River Culvert Assessment (2012)
Geomorphic Compatibility and Aquatic Organism Passage (AOP)**

Reach/ Segment Number	Town	Road Name	Structure Type and ID ¹	Percent Bankfull Channel Width ²	Phase 2 Notes	Scoring (Geomorphic Compatibility - Milone & MacBroom, 2008; AOP – Milone & MacBroom, 2009)							
						% Bankfull Width ⁵	Sediment Continuity	Slope	Approach Angle	Erosion & Armoring	Total Score	Geomorphic Compatibility	AOP
T2.13-A	Dover	Handle Road	N/A	66	Scour below.	2	2	0	2	0	6/25	Mostly Incompatible	No AOP Including Adult Salmonids
T2.14-A	Dover	North Access Road	N/A	64	Two culverts side by side. Deposition above and scour below.	2	4	2	2	1	11/25	Partially Compatible	No AOP Except Adult Salmonids

¹The structure ID is the identification number provided by the 2010 "TransStructures_TRANSTRUC" shapefile from the Vermont Center for Geographic Information, unless no number was available.

²Percent Bankfull Channel Width percentages are calculated based on the reference channel width for each reach. The percentage is calculated by dividing the culvert width by the reference channel width.

North Branch of the Deerfield River Watershed 2012 Bridge & Culvert Assessments in Wilmington



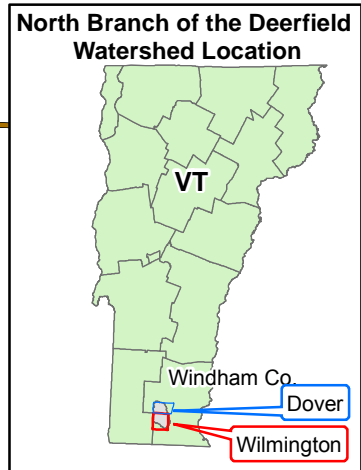
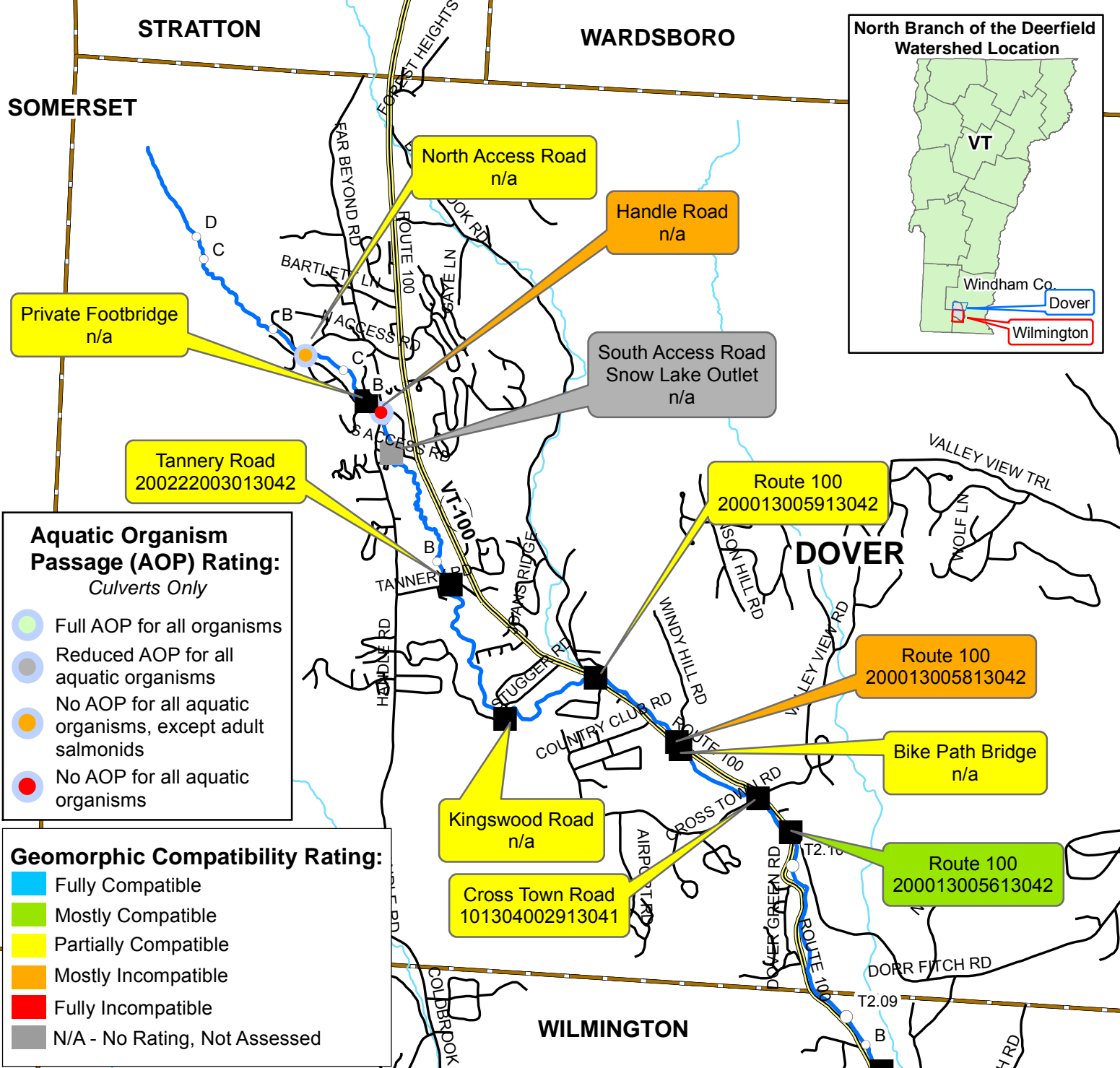
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Geomorphic Compatibility Rating for bridges is adapted from the Vermont Culvert Geomorphic Compatibility Screening Tool (Milone and MacBroom, Inc. 2008).



North Branch of the Deerfield River Watershed 2012 Bridge & Culvert Assessments in Dover



The ID numbers are provided by the 2010 "TransStructures _TRANSTRUC" shapefile from the Vermont Center for Geographic Information, unless no number was available.

Geomorphic Compatibility Rating for bridges is adapted from the Vermont Culvert Geomorphic Compatibility Screening Tool (Miloneand MacBroom, Inc. 2008).

Aquatic Organism Passage Rating for culverts is from the Vermont Culvert Aquatic Organism Passage Screening Tool (Milone and MacBroom, 2009).



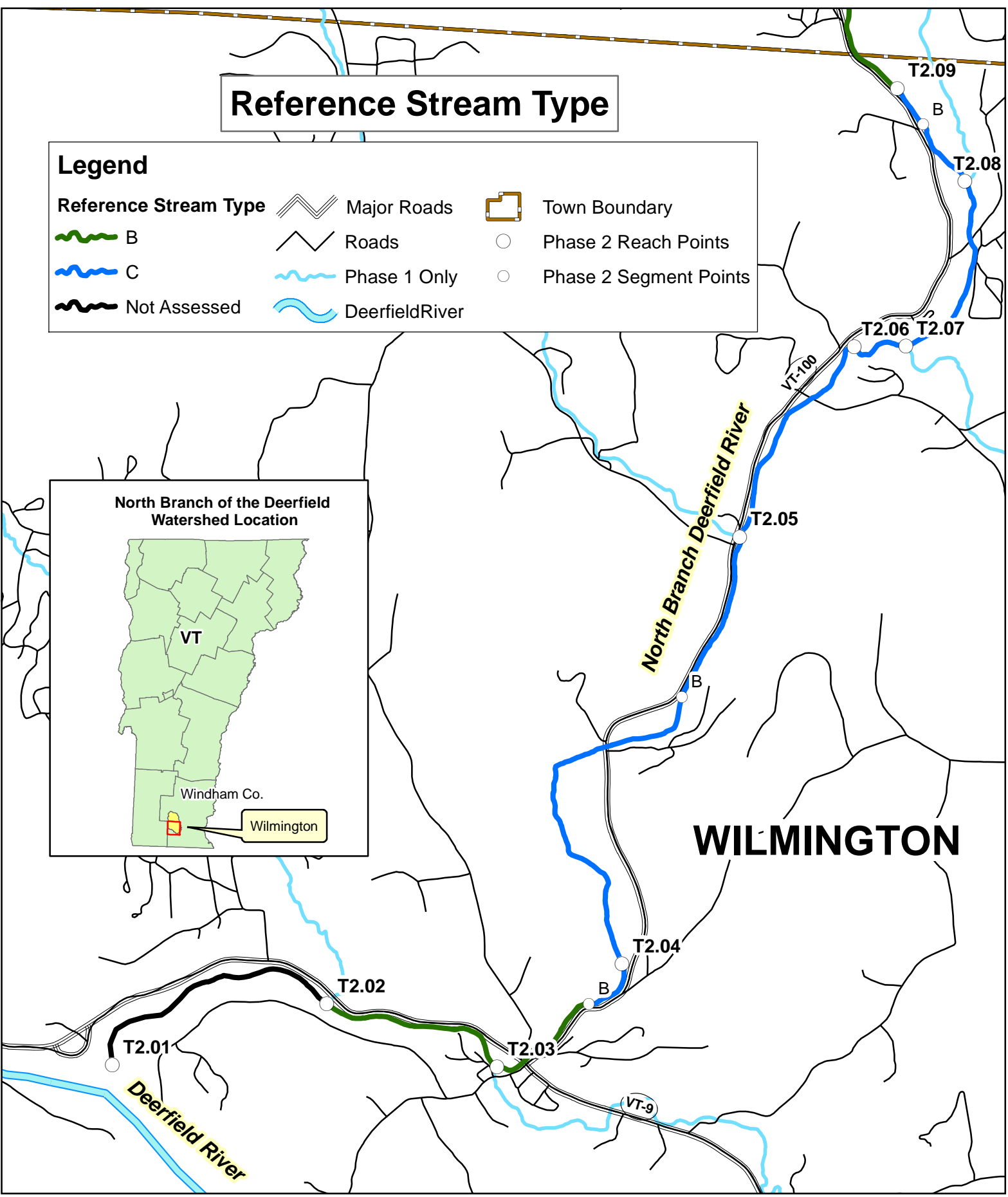
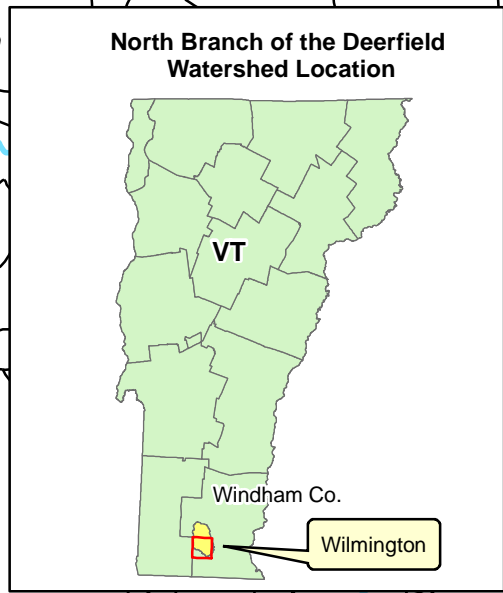
APPENDIX B

Maps

Reference Stream Type

Legend

Reference Stream Type	Major Roads	Town Boundary
B	Roads	Phase 2 Reach Points
C	Phase 1 Only	Phase 2 Segment Points
Not Assessed	Deerfield River	

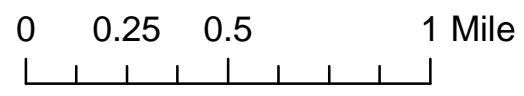
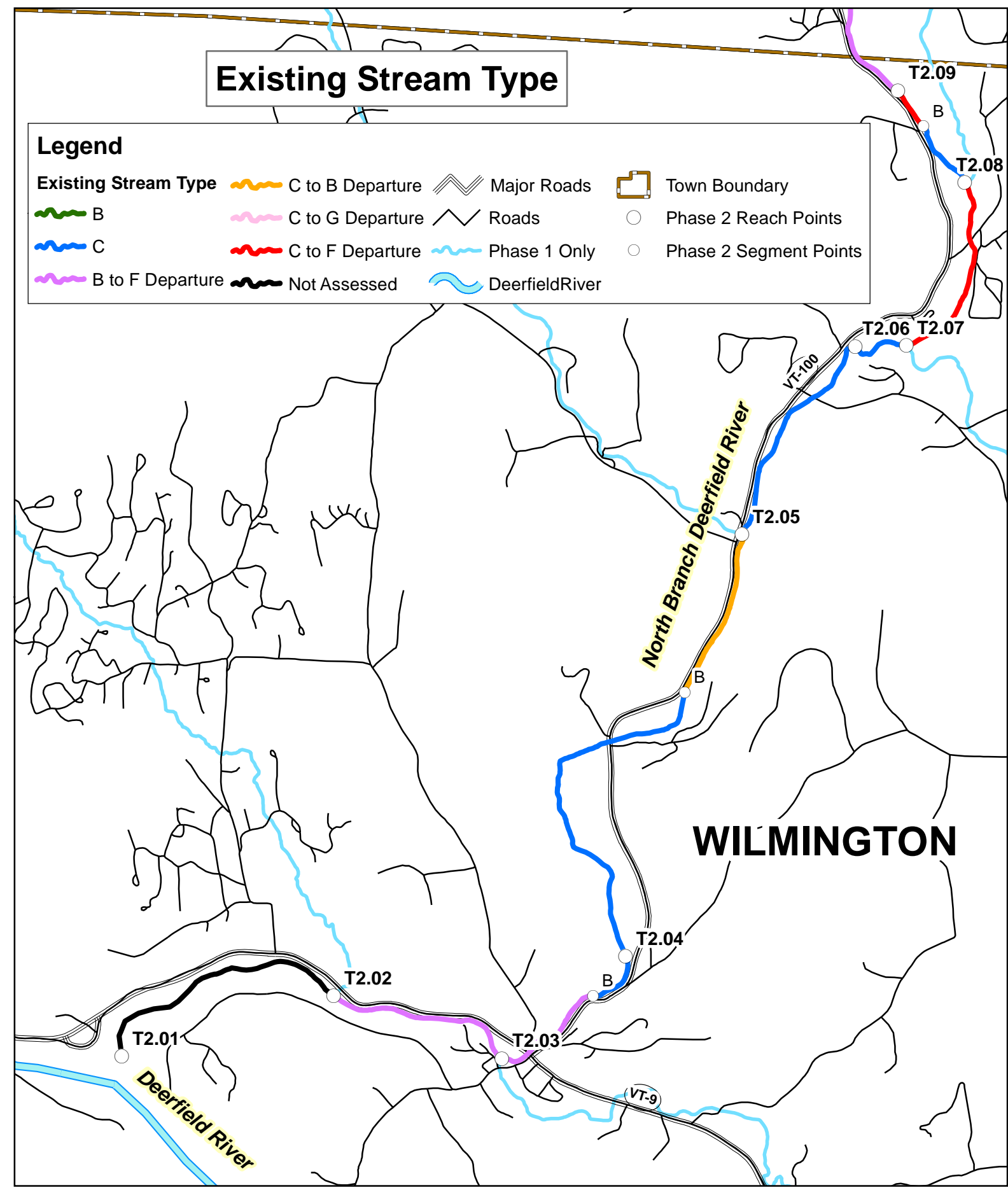


North Branch of the Deerfield River Stream Types - Wilmington

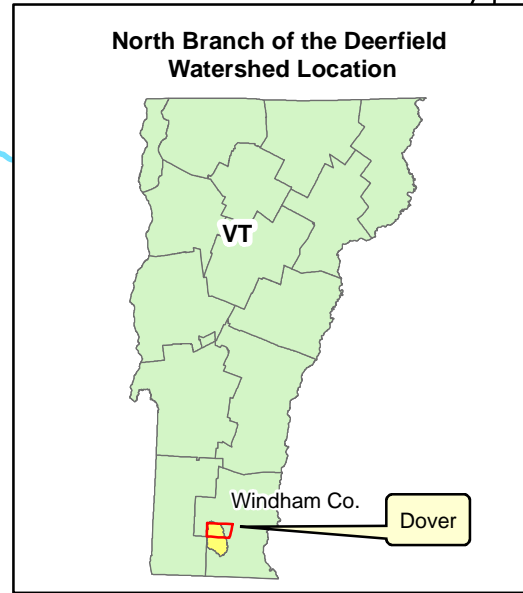
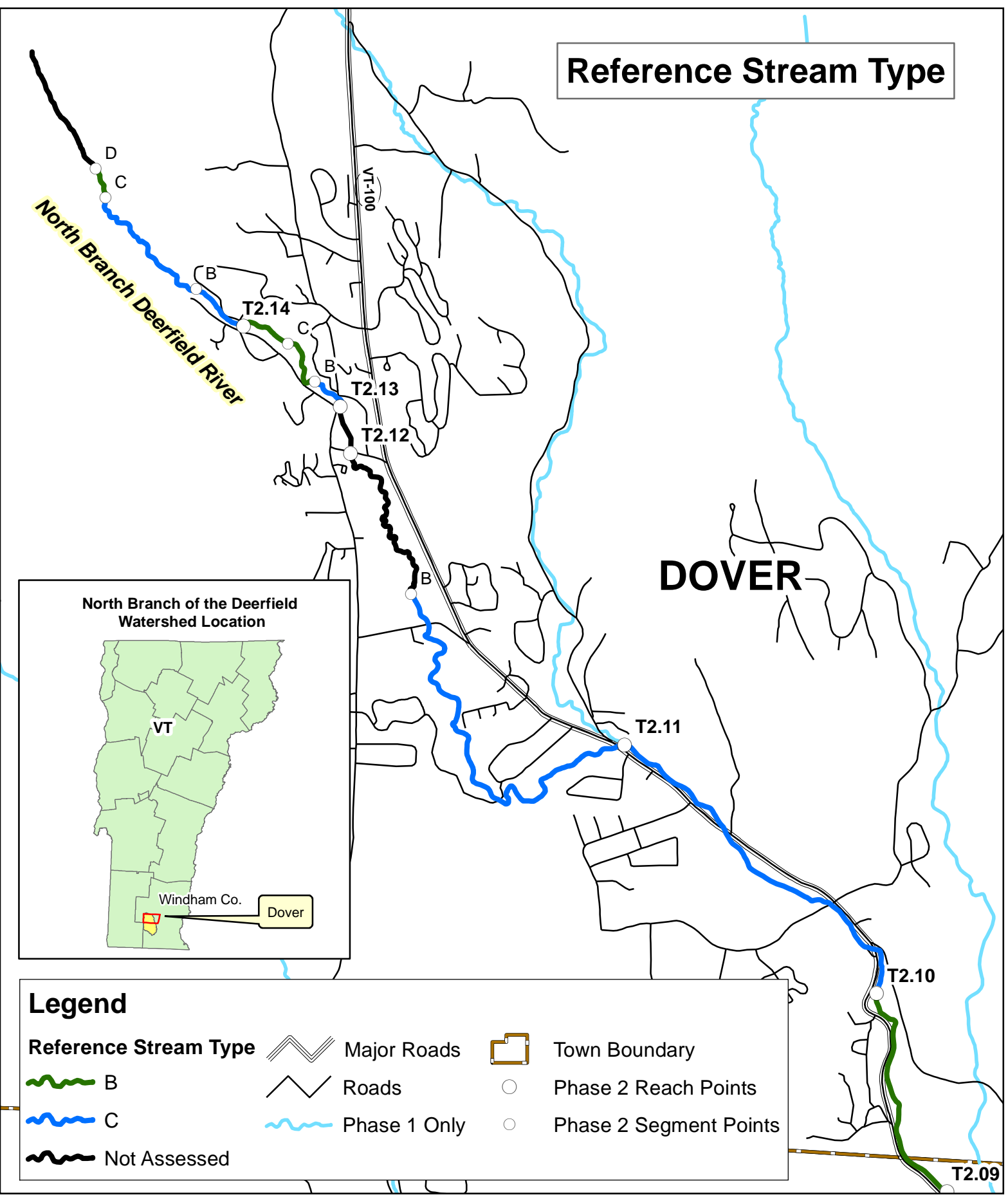
Existing Stream Type

Legend

Existing Stream Type	C to B Departure	Major Roads	Town Boundary
B	C to G Departure	Roads	Phase 2 Reach Points
C	C to F Departure	Phase 1 Only	Phase 2 Segment Points
B to F Departure	Not Assessed	Deerfield River	



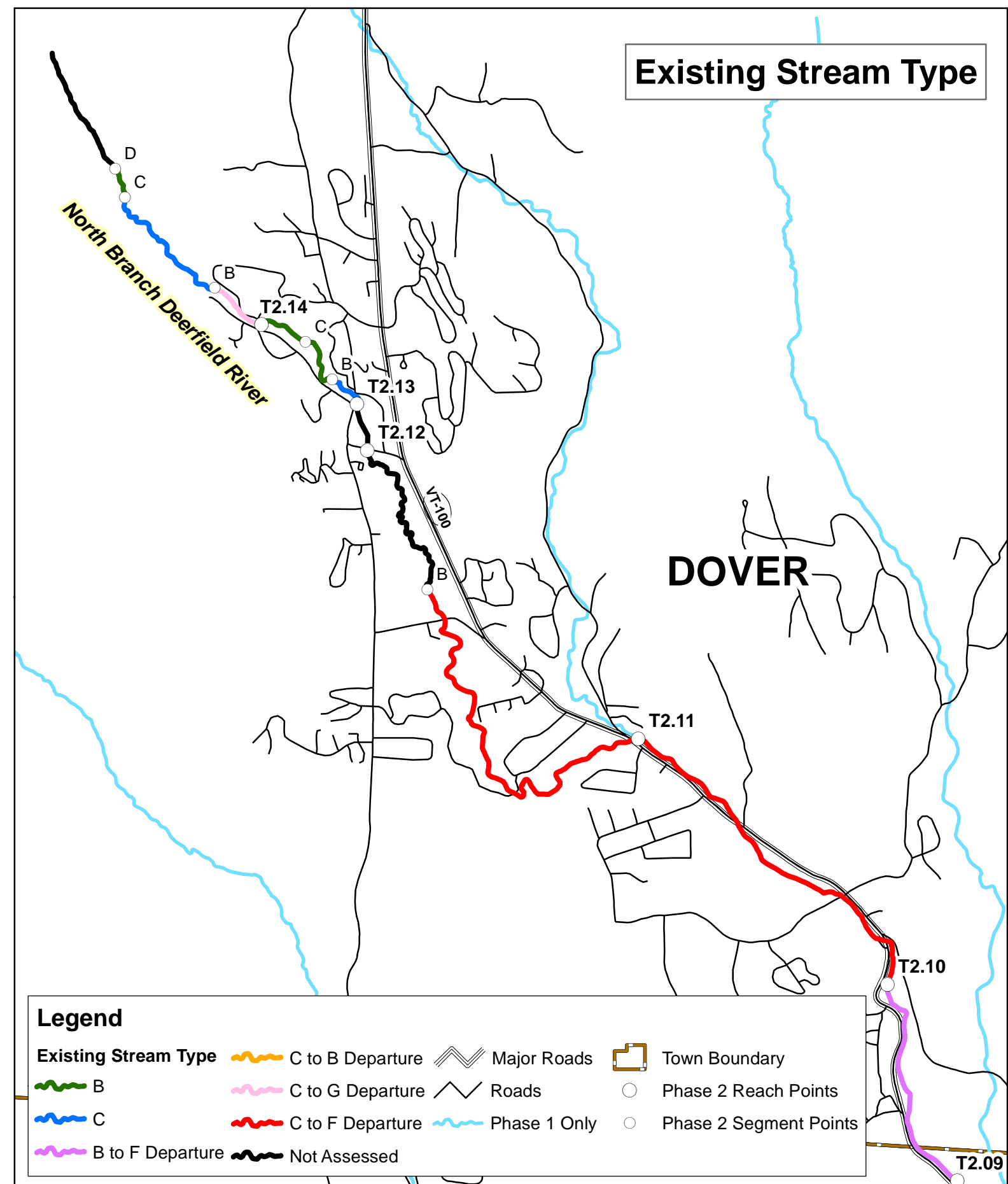
Reference Stream Type



Legend

Reference Stream Type	Major Roads	Town Boundary
B	Roads	Phase 2 Reach Points
C	Phase 1 Only	Phase 2 Segment Points
Not Assessed		

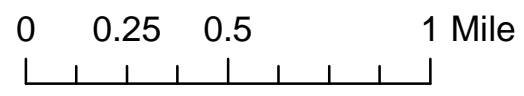
Existing Stream Type

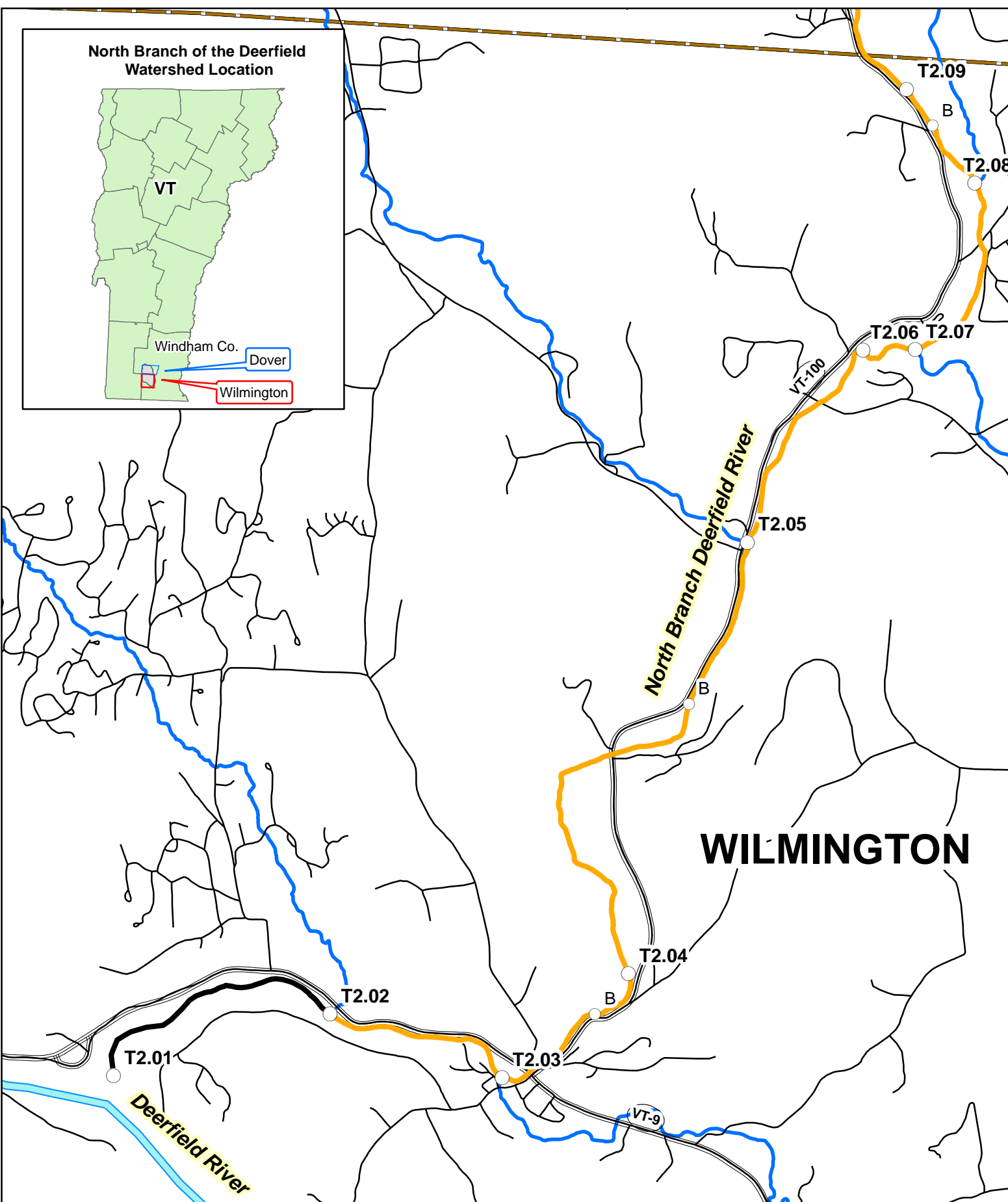


Legend

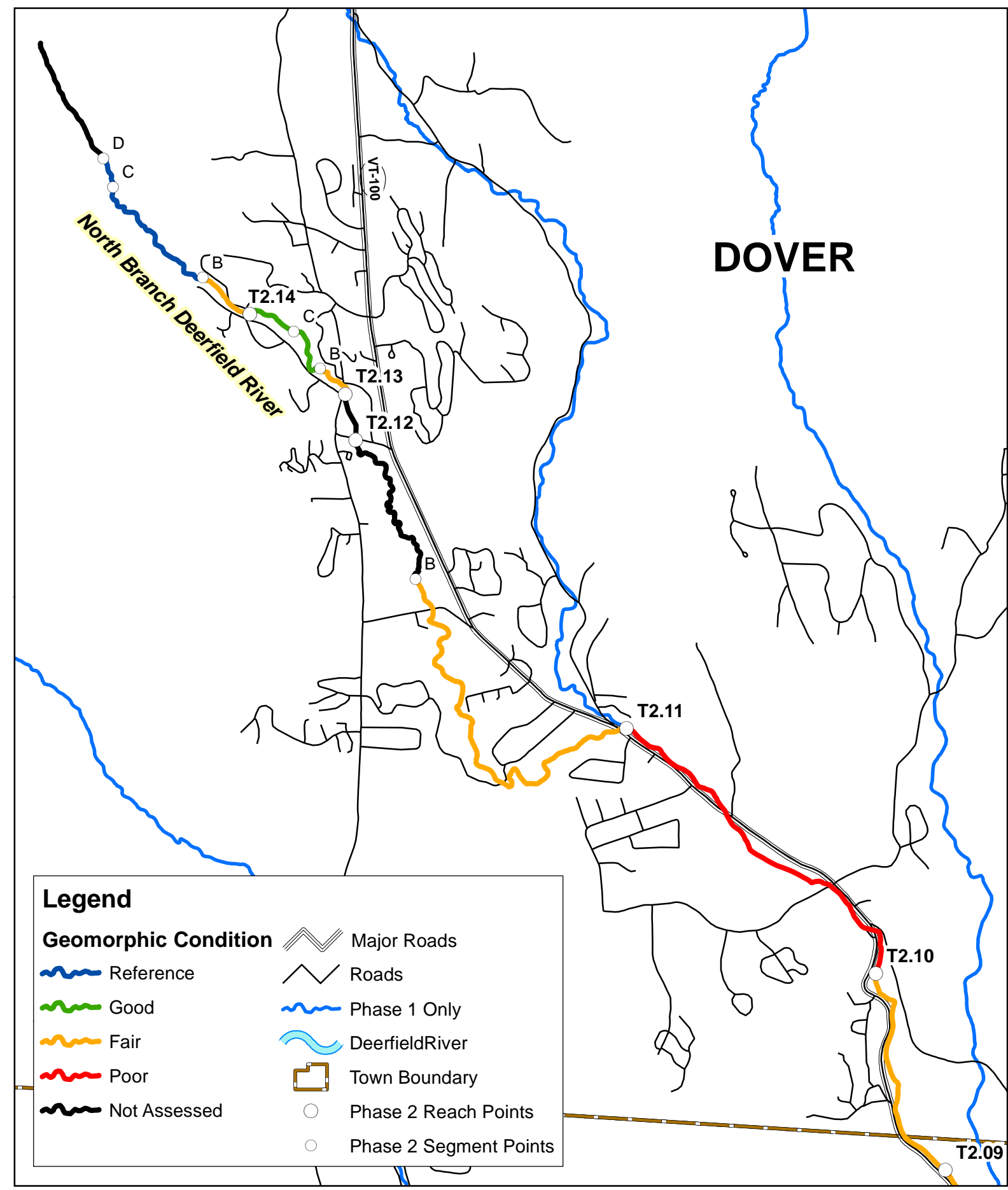
Existing Stream Type	C to B Departure	Major Roads	Town Boundary
B	C to G Departure	Roads	Phase 2 Reach Points
C	C to F Departure	Phase 1 Only	Phase 2 Segment Points
B to F Departure	Not Assessed		

North Branch of the Deerfield River Stream Types - Dover

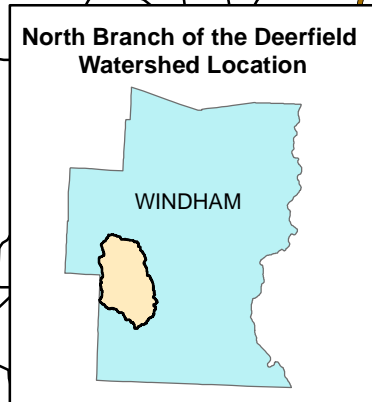
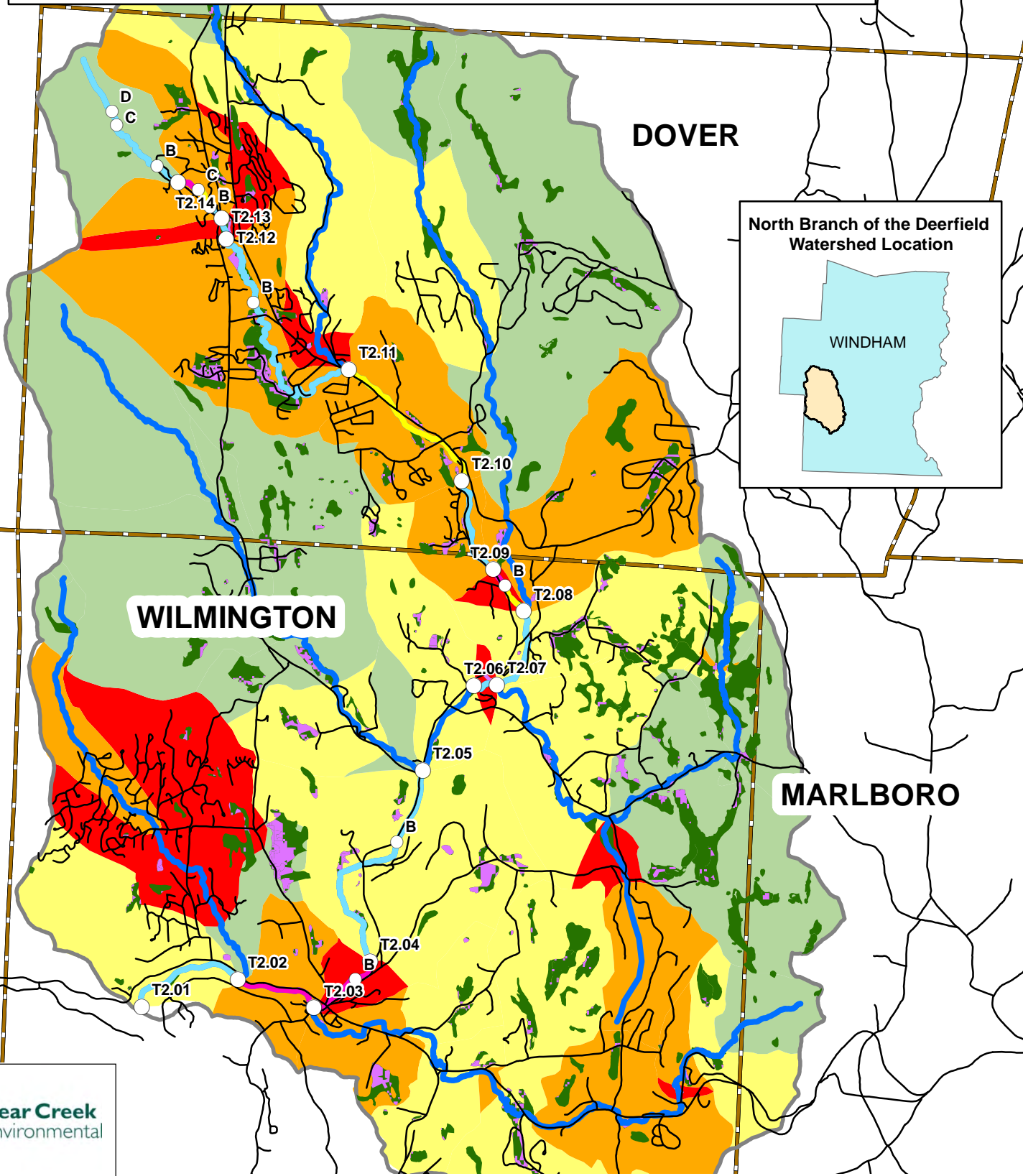
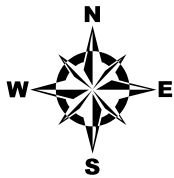




**North Branch of the Deerfield River
Geomorphic Condition**



North Branch of the Deerfield River Watershed Hydrologic Regime Map

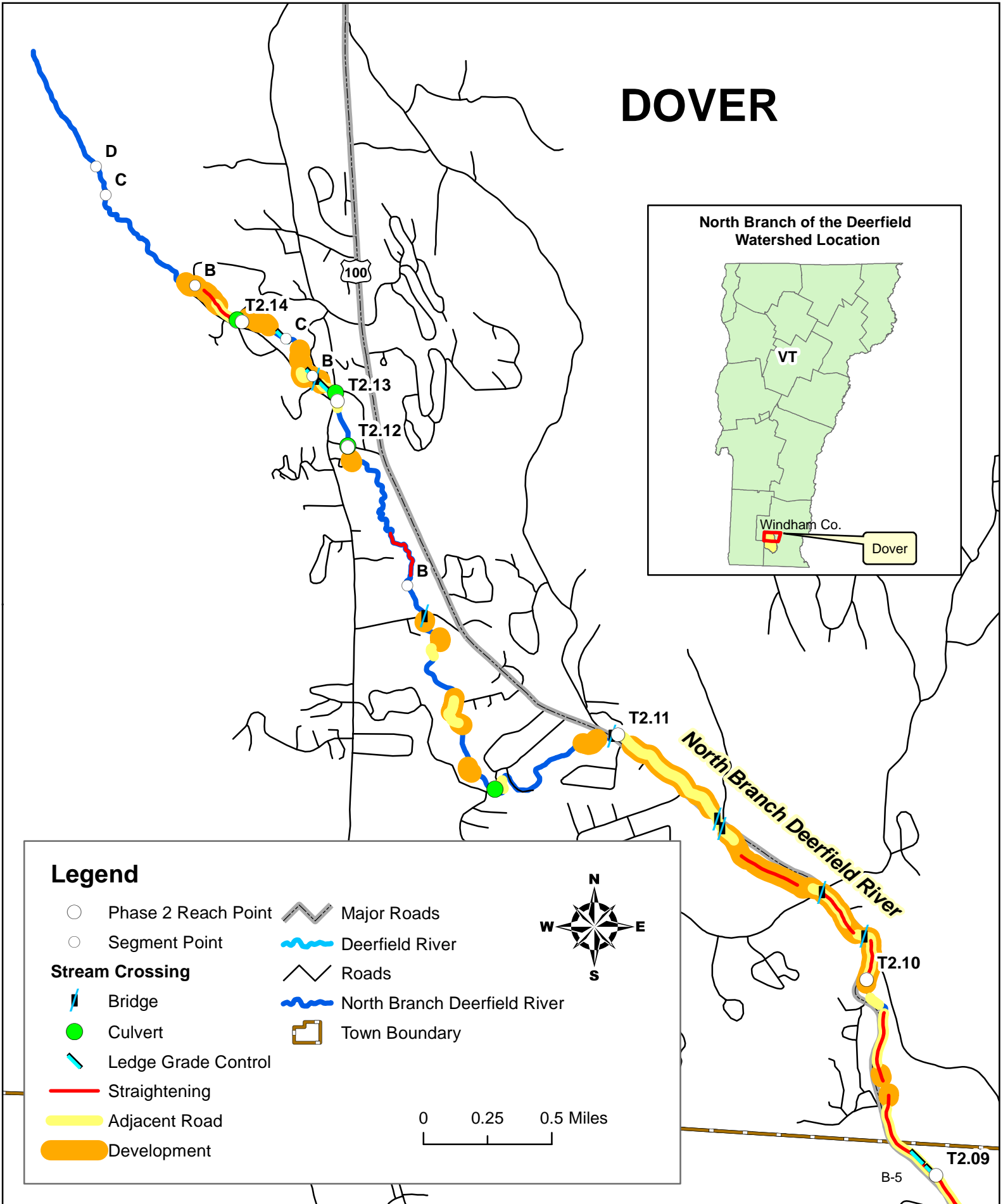
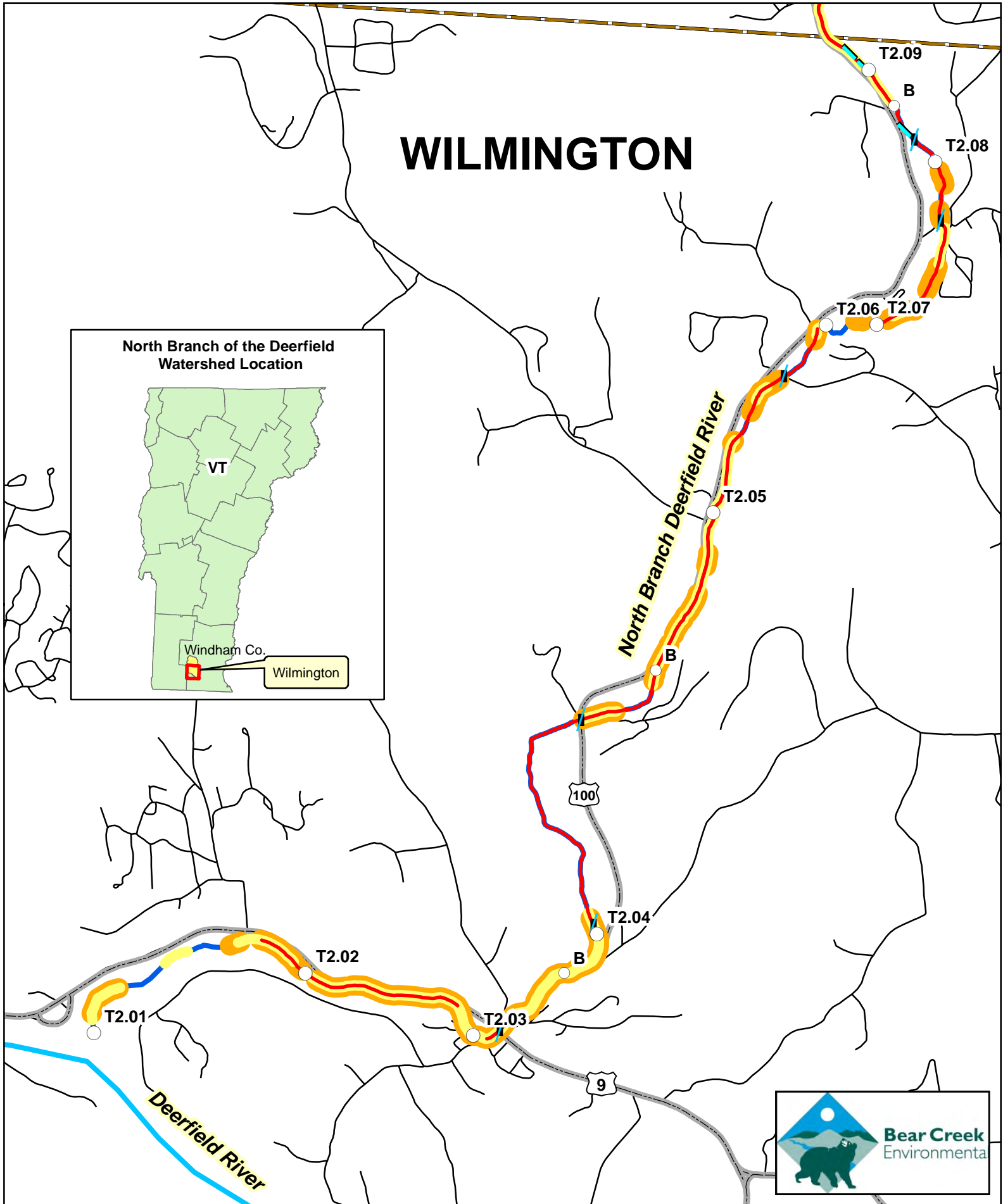


Legend

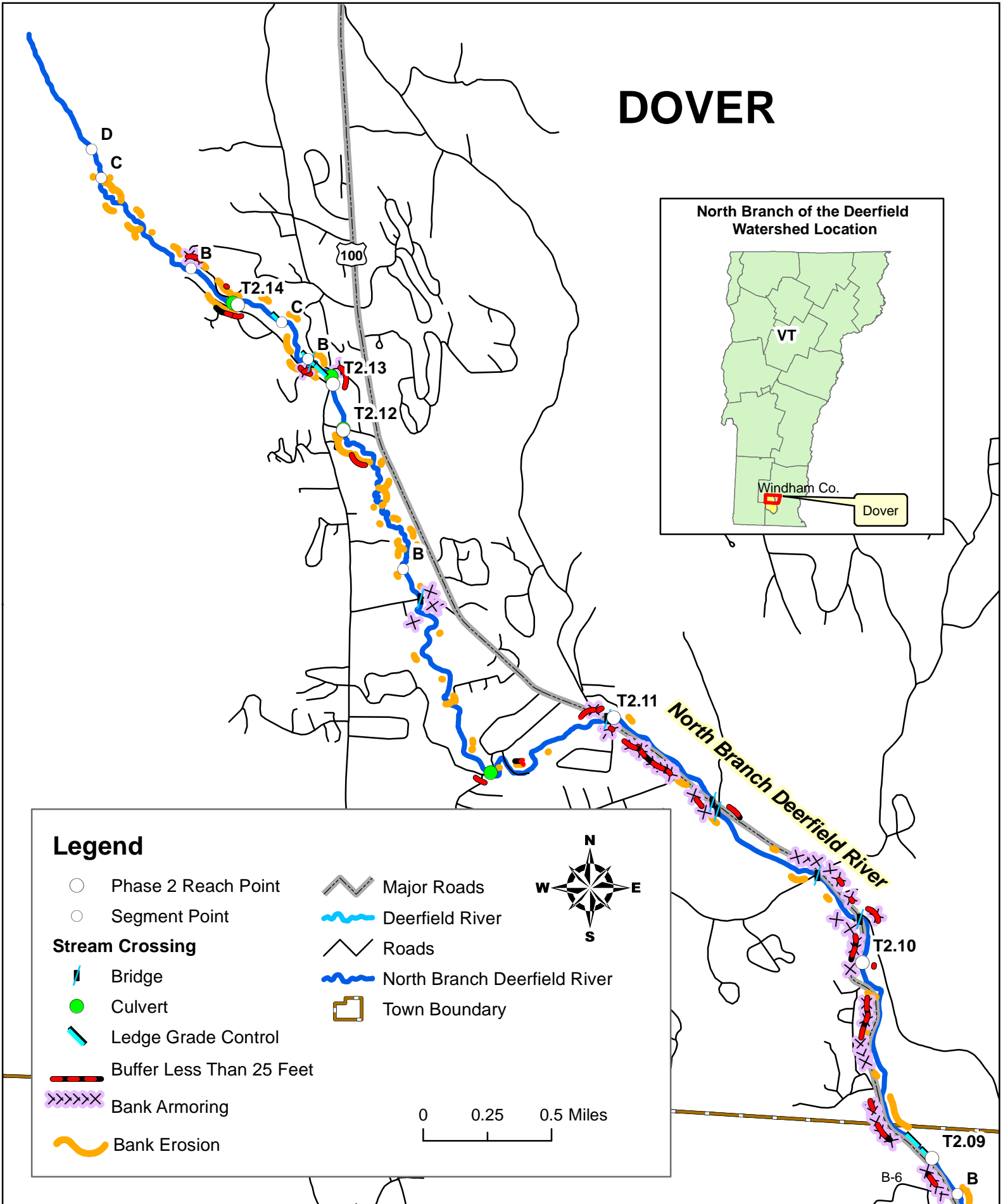
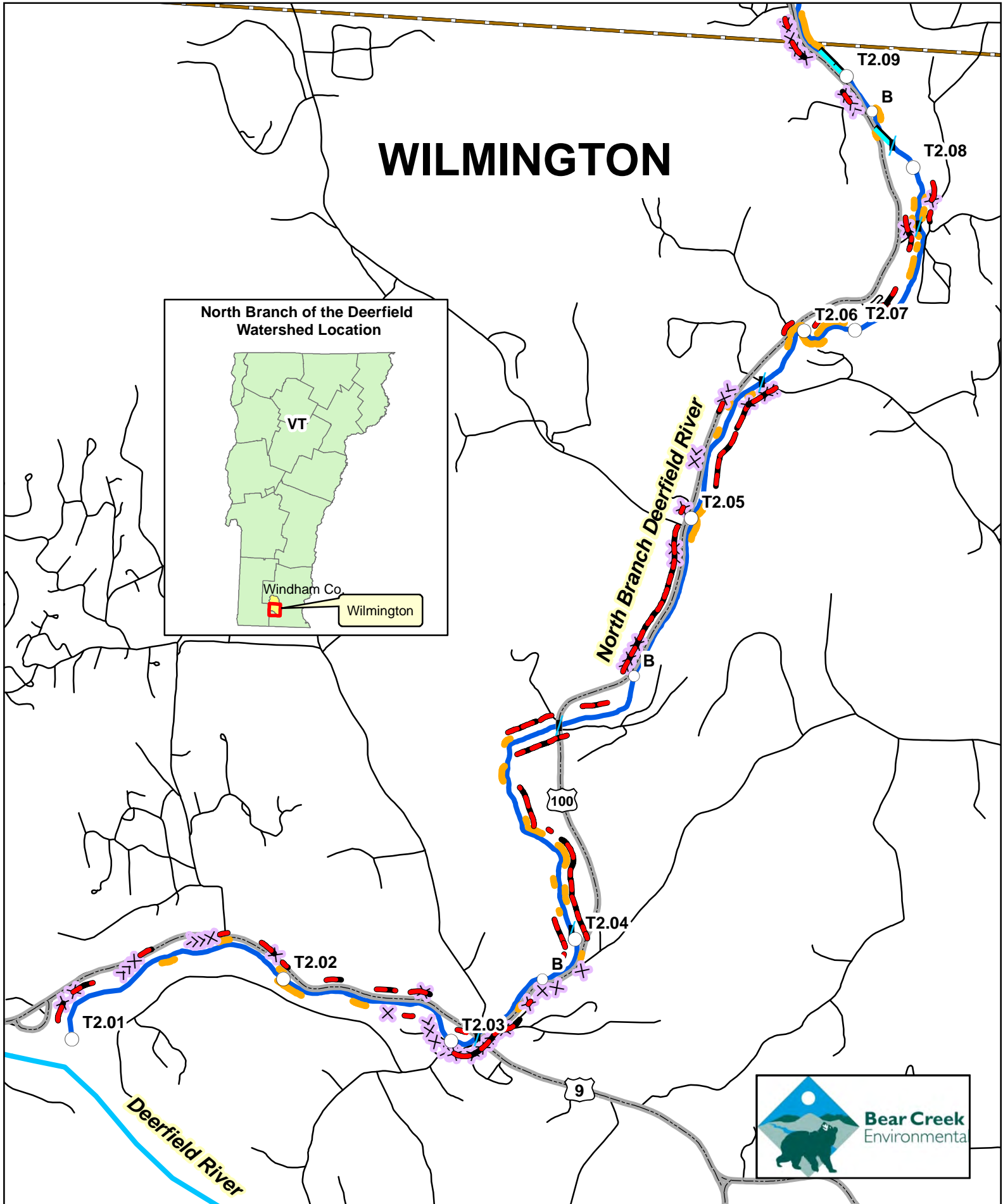
○ Phase 2 Reach Point	▭ Town Boundary	Stormwater Inputs/Mile	Road Density (mi/sqmi)
○ Segment Point	⊖ North Branch Deerfield River Watershed	None	0-2
⦿ Phase 1 Only	🌿 Intact Wetland	>2 <= 5	2-4
⚡ Roads	⊕ Wetland Loss	> 5	4-6 B-4
			6-13

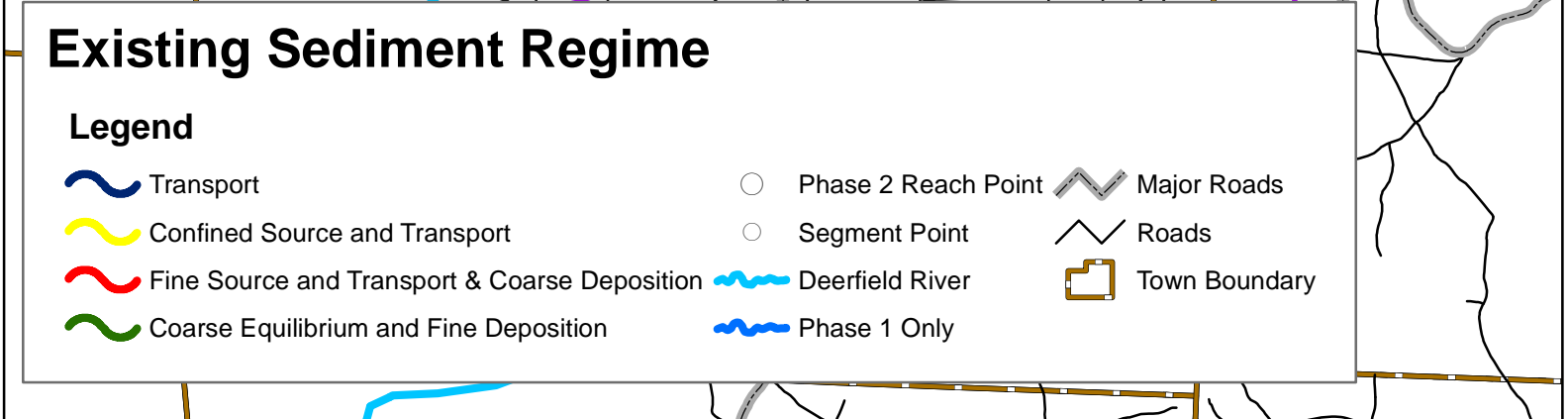
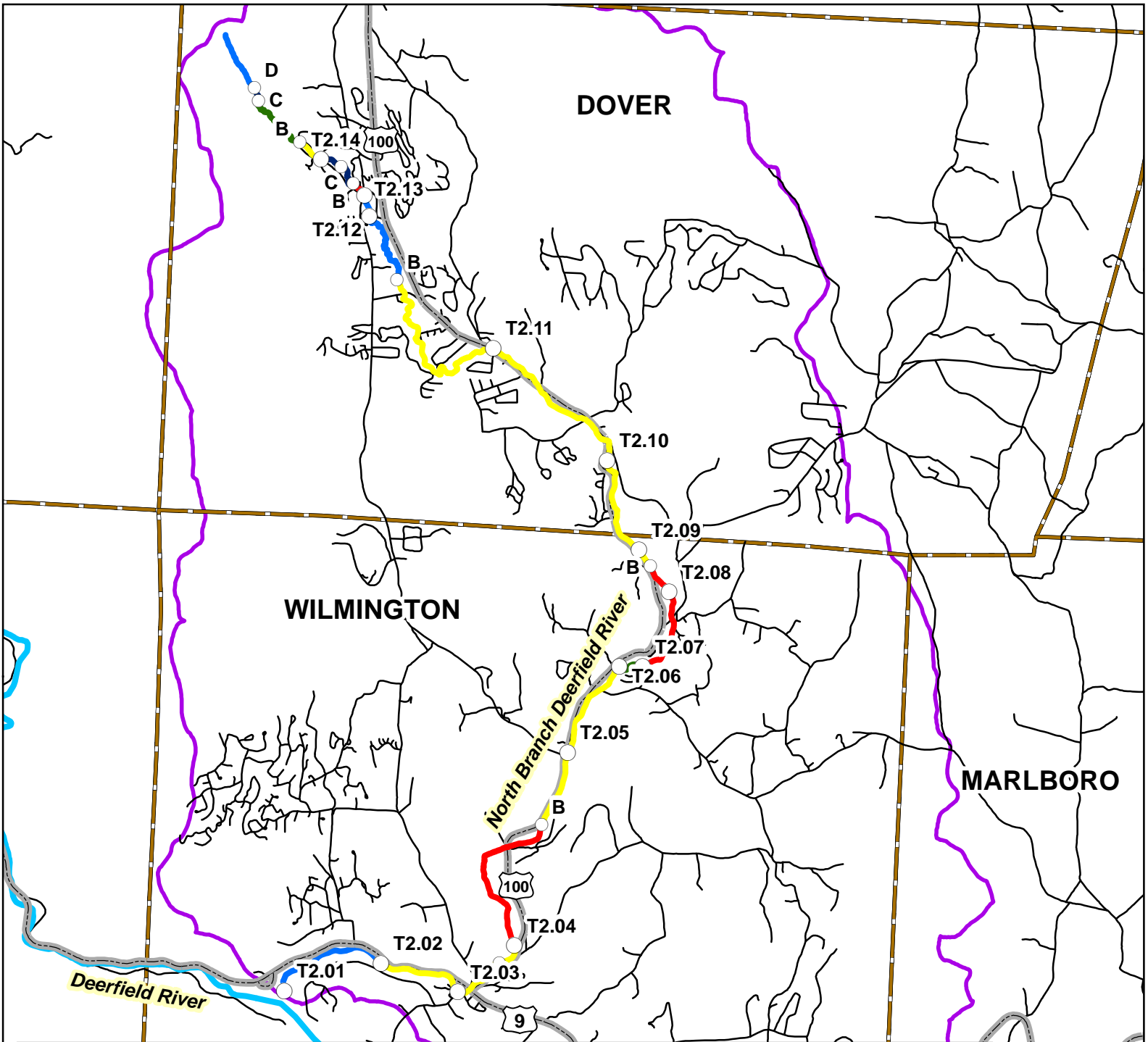
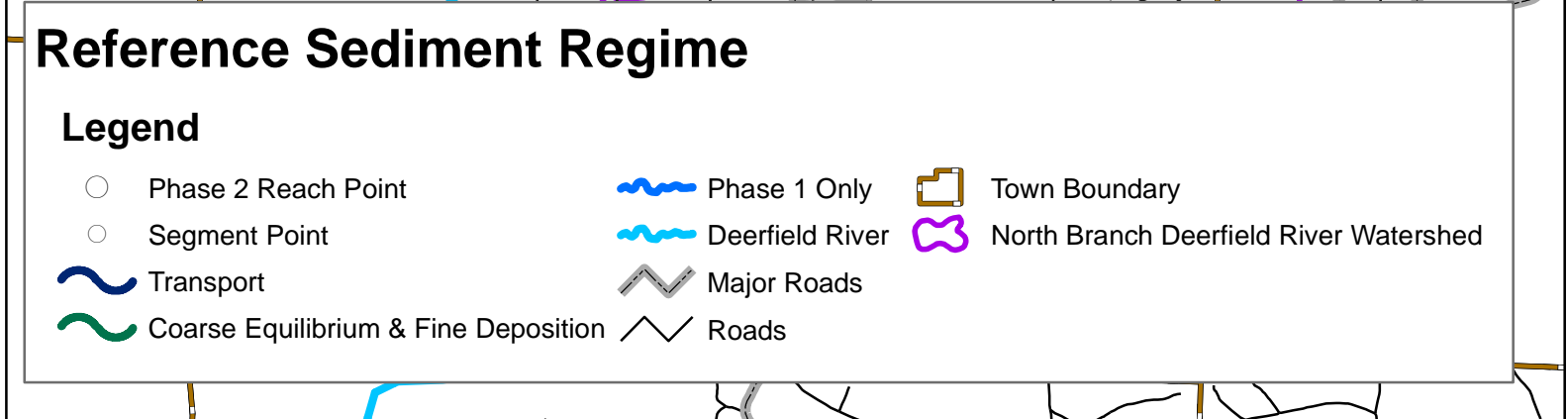
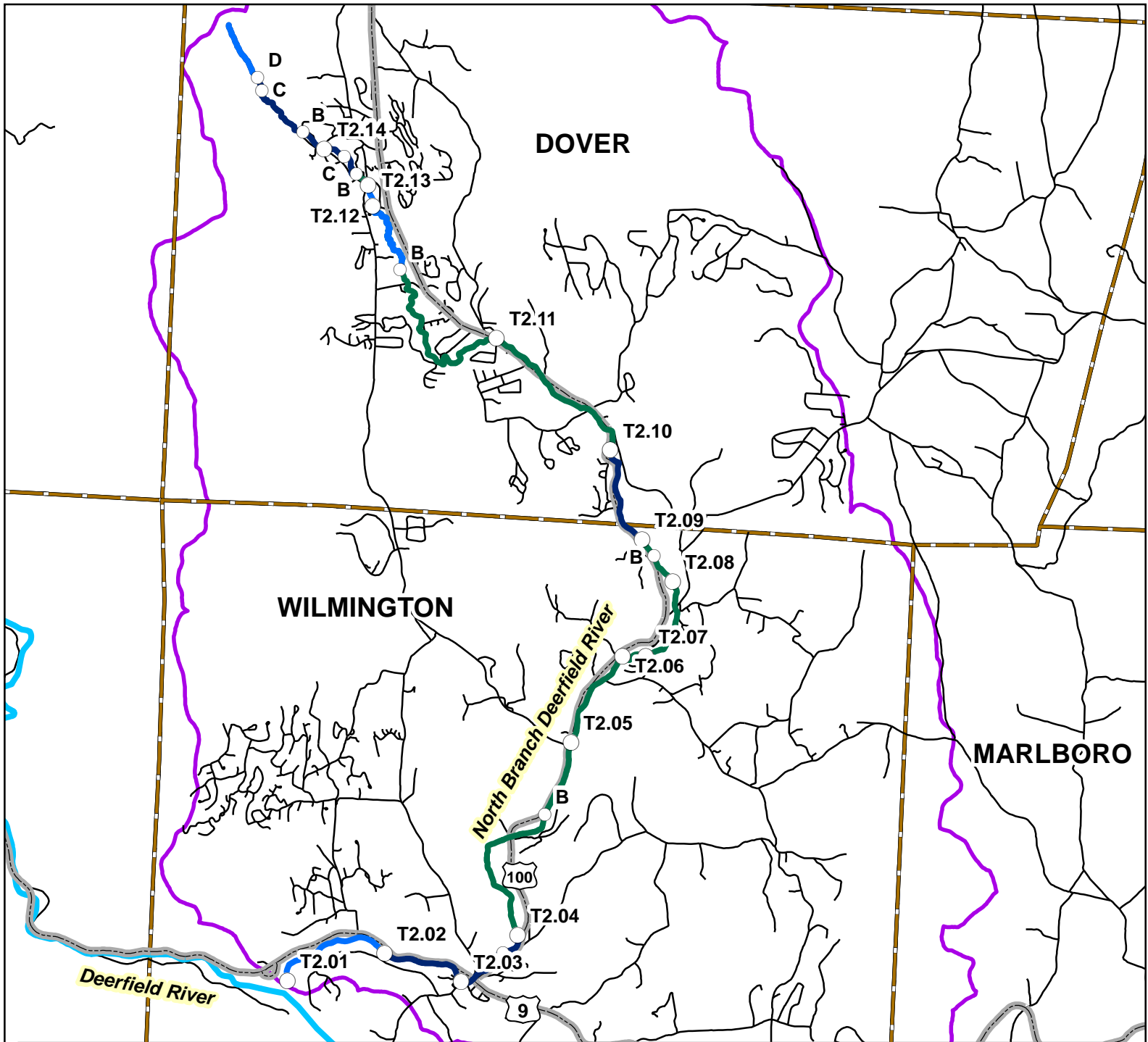
0 0.5 1 Mile

North Branch of the Deerfield River Watershed Channel Slope Modifiers

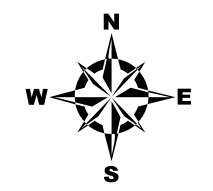
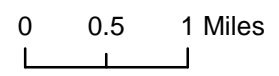


North Branch of the Deerfield River Watershed Riparian and Boundary Conditions

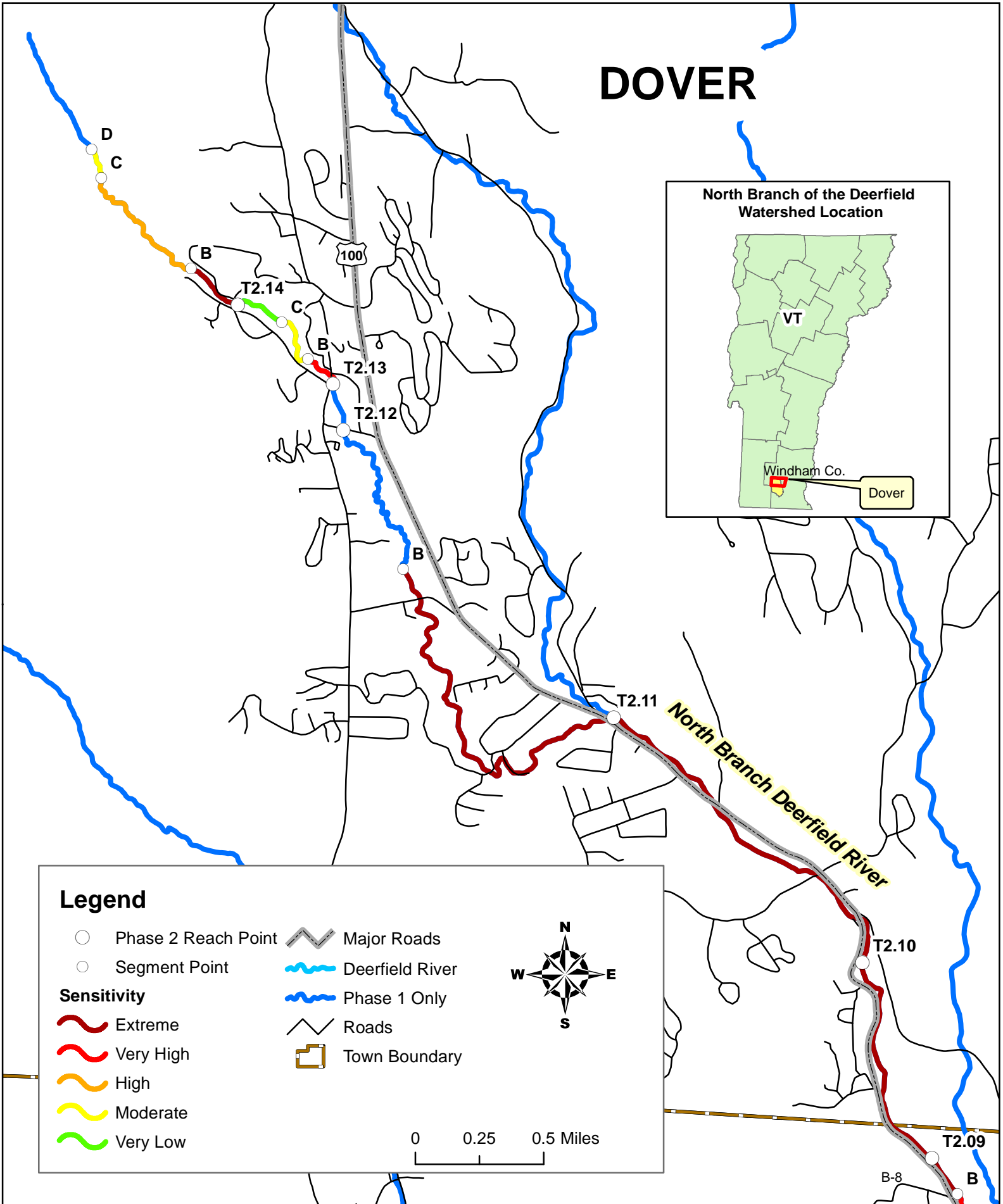
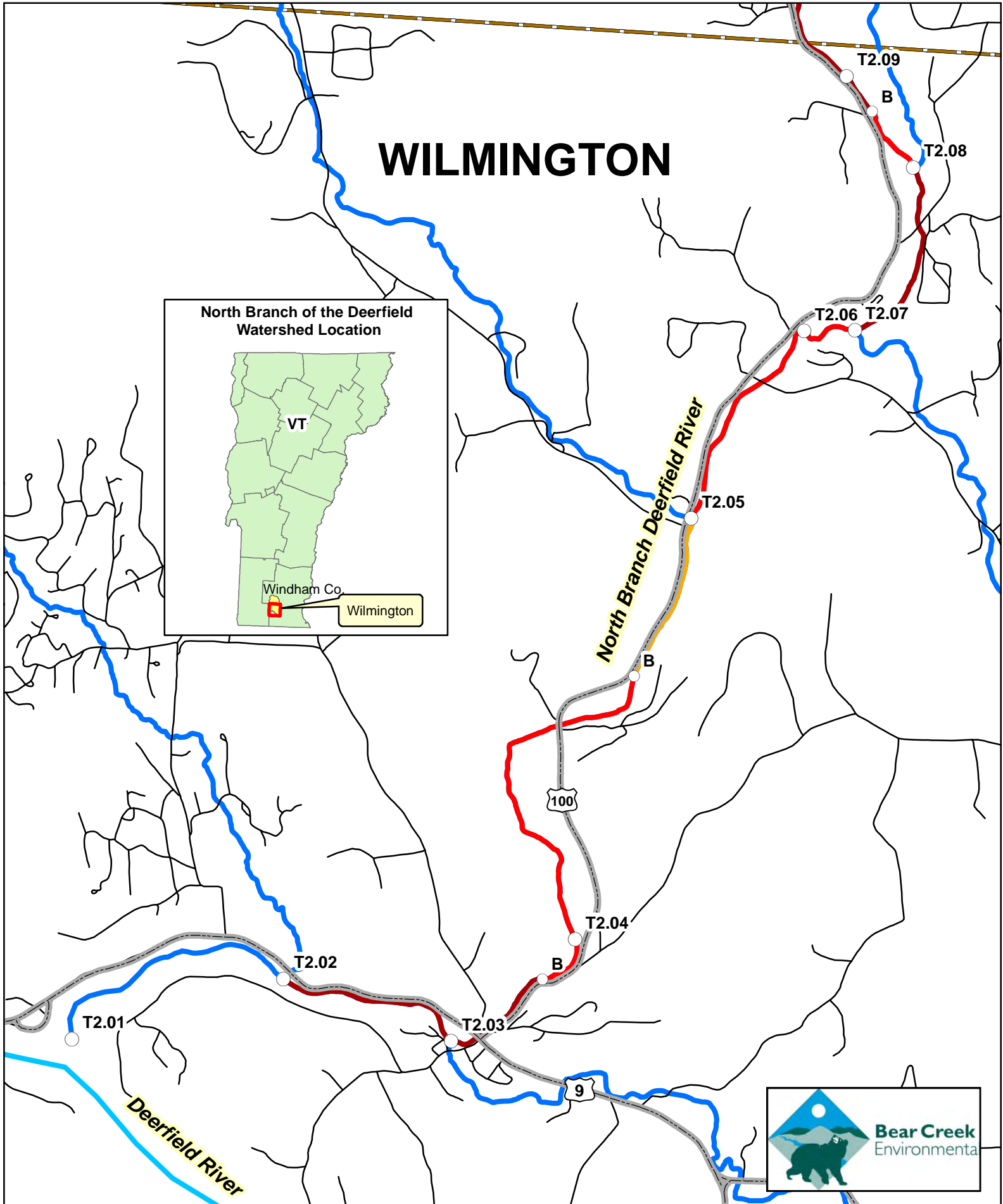




North Branch of the Deerfield River Watershed Sediment Regime



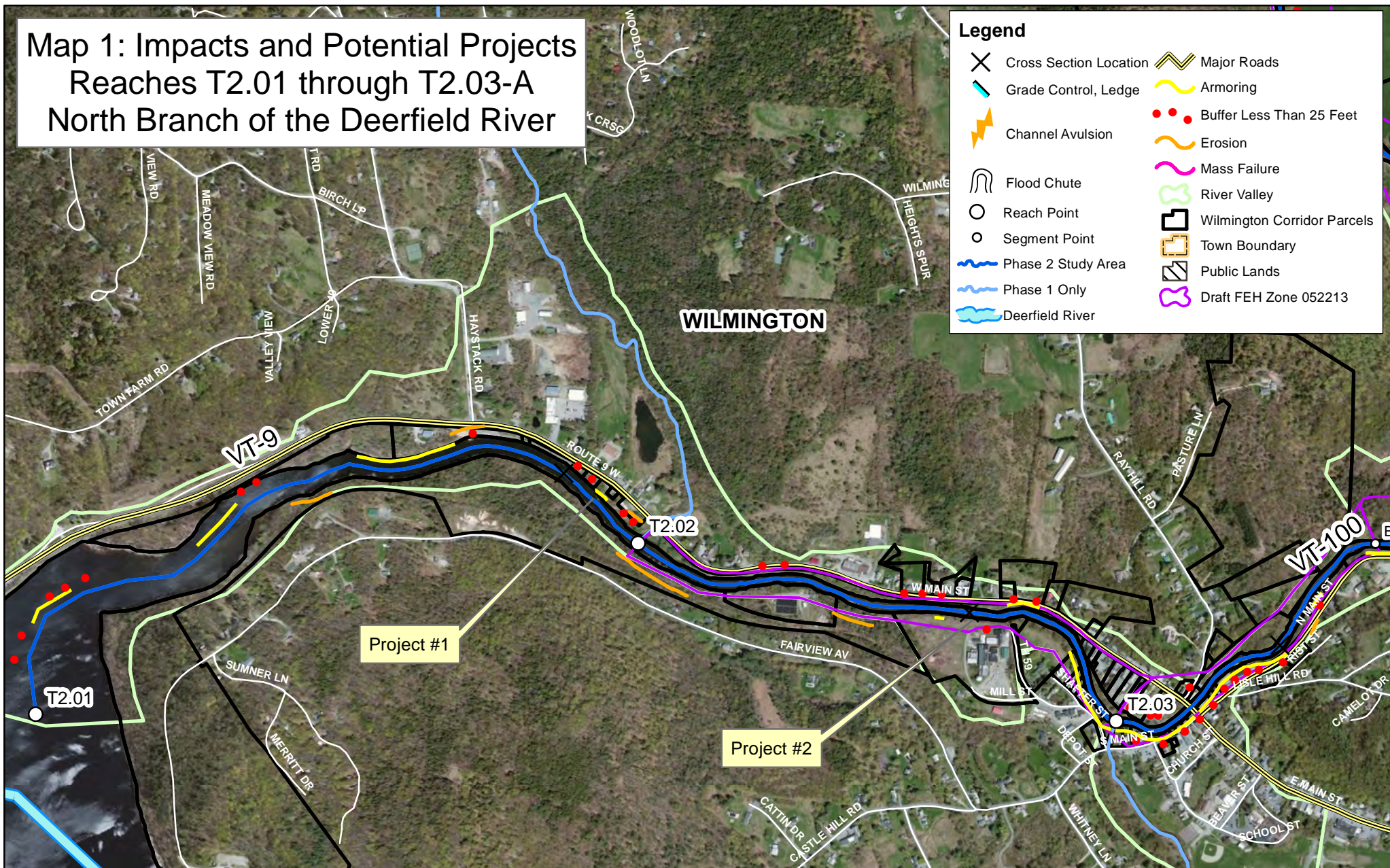
North Branch of the Deerfield River Watershed Stream Sensitivity



APPENDIX C

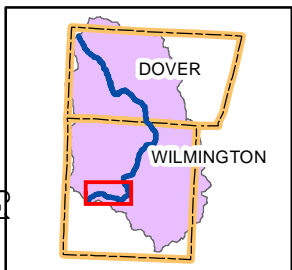
Potential Project Locations & Descriptions

Map 1: Impacts and Potential Projects Reaches T2.01 through T2.03-A North Branch of the Deerfield River



Legend

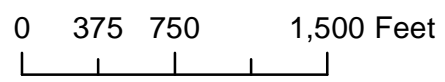
	Cross Section Location		Major Roads
	Grade Control, Ledge		Armoring
	Channel Avulsion		Buffer Less Than 25 Feet
	Flood Chute		Erosion
	Reach Point		Mass Failure
	Segment Point		River Valley
	Phase 2 Study Area		Wilmington Corridor Parcels
	Phase 1 Only		Town Boundary
	Deerfield River		Public Lands
			Draft FEH Zone 052213



Projects:
 1. Reduce Encroachment
 2. Remove Old Abutment

Project Priority:

	Low
	Moderate
	High

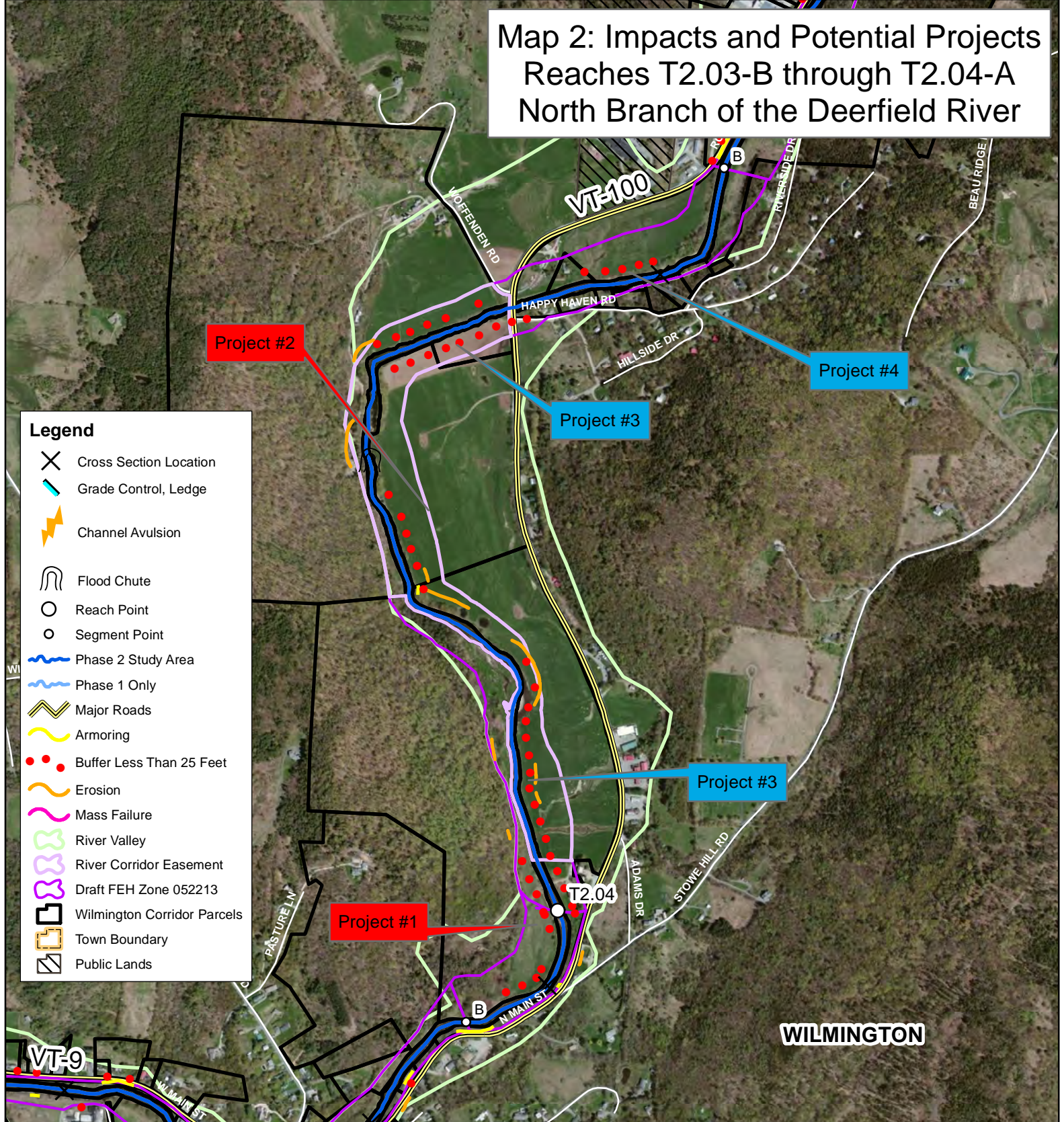


Background is Bing Imagery

**Table 1. North Branch of the Deerfield River Main Stem
Map 1: T2.01 through T2.03-A
Site Level Opportunities for Restoration and Protection
Wilmington, Vermont**

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Potential Partners/Programs
Project #1 T2.01	Active Restoration	Old bridge abutment was noted on the field map in 2005. This abutment appears to have been replaced by a ramp to install riprap in this area, which is causing a channel constriction. The road was completely washed out during Tropical Storm Irene.	Reduce encroachment	Low Priority (Area impounded by Harriman Reservoir)	NA	Unknown	Town of Wilmington, VTrans, VANR, WRC
Project #2 T2.02	Active Restoration	Old dam is noted on field map, but is not listed as a channel constriction. According to local knowledge, this structure is actually an old abutment. Abutment is minor channel constriction and bottom of structure is at grade.	Remove old dam	Low Priority (abutment does not appear to be causing major geomorphic instability)	NA	NA	WRC, CRWC, VANR

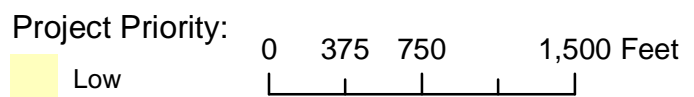
Map 2: Impacts and Potential Projects Reaches T2.03-B through T2.04-A North Branch of the Deerfield River



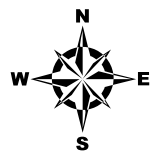
Legend

- Cross Section Location
- Grade Control, Ledge
- Channel Avulsion
- Flood Chute
- Reach Point
- Segment Point
- Phase 2 Study Area
- Phase 1 Only
- Major Roads
- Armoring
- Buffer Less Than 25 Feet
- Erosion
- Mass Failure
- River Valley
- River Corridor Easement
- Draft FEH Zone 052213
- Wilmington Corridor Parcels
- Town Boundary
- Public Lands

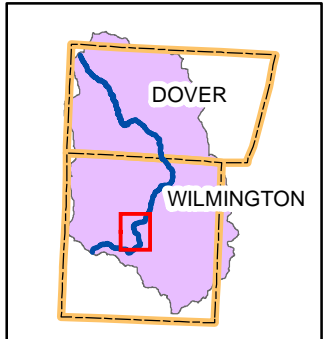
- Projects:**
1. Streamside Plantings
 2. River Corridor Easement
 3. Streamside Plantings
 4. Streamside Plantings



- Low
- Moderate
- High



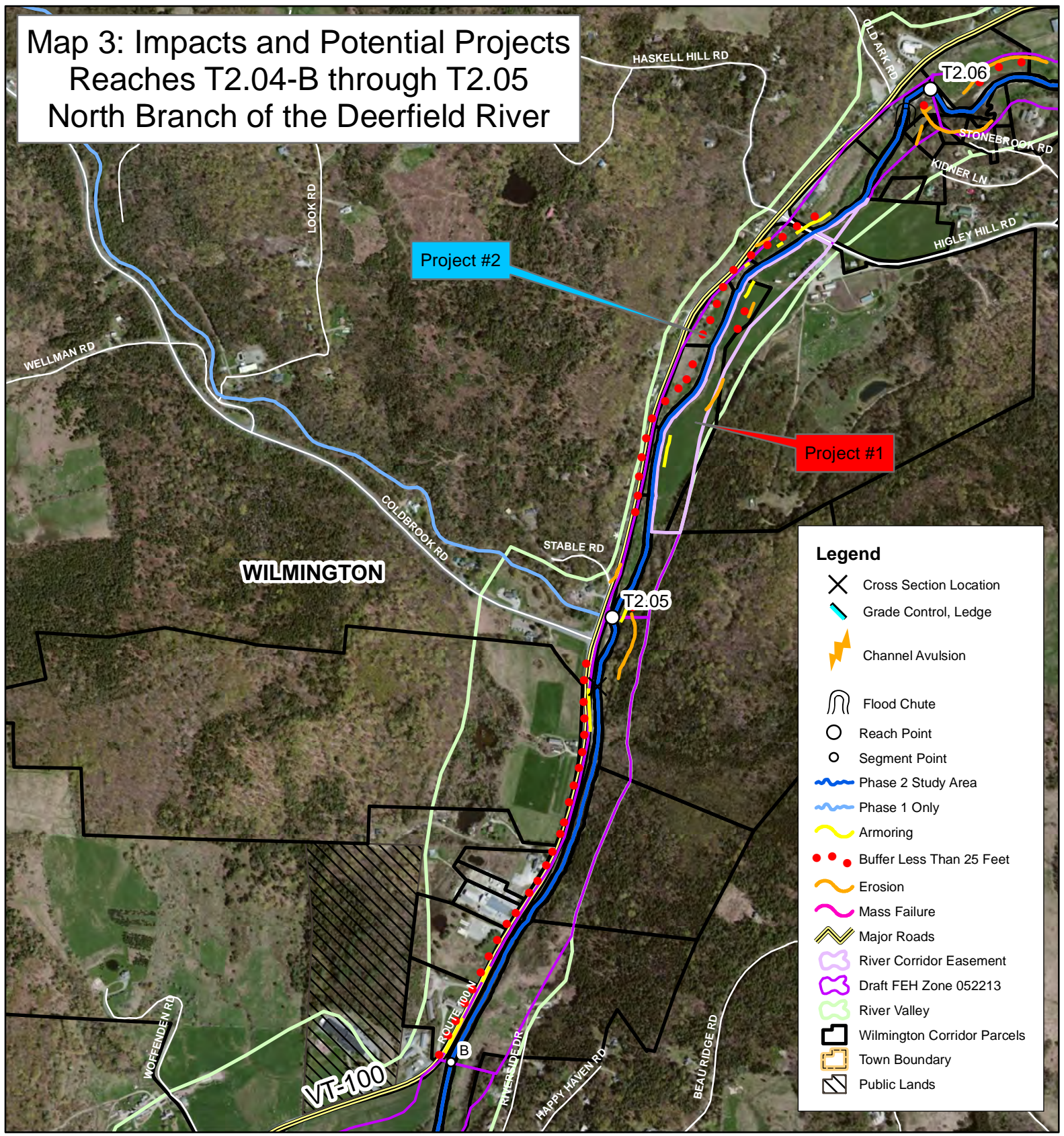
Background is Bing Imagery
C-3



**Table 2. North Branch of the Deerfield River Main Stem
Map 2: T2.03-B through T2.04-A
Site Level Opportunities for Restoration and Protection
Wilmington, Vermont**

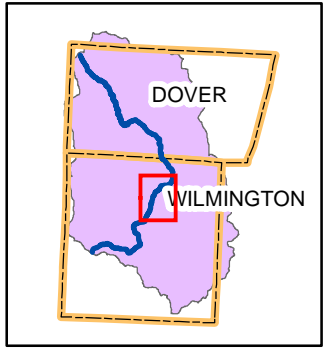
Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Potential Partners/Programs
Project #1 T2.03-B & T2.04-A	Passive	Western bank along agricultural field lacks adequate buffer.	Streamside plantings, away from channel – river is widening.	High Priority	Improved habitat, water quality, and geomorphic stability	Cost of plantings	Landowner, Windham County NRCD, WRC, CRWC, VCF, VANR, Town of Wilmington CREP, TFS, WHIP
Project #2 T2.04-A	Passive Restoration	Channel has fair to good floodplain access along agricultural fields	Protect river through corridor easement	High Priority	Flood resiliency; improved habitat, water quality, and geomorphic stability	Cost of easement	Landowners, WRC, VANR, Town of Wilmington RCE
Project #3 T2.04-A	Passive Restoration	Areas along agricultural fields that lack adequate buffer	Streamside plantings, plant away from channel – river is widening	Moderate Priority	Improved habitat and water quality	Cost of plantings	Landowners, Windham County NRCD, WRC, CRWC, VCF, VANR, Town of Wilmington CREP, TFS, WHIP
Project #4 T2.04-A	Passive Restoration	Northern bank along agricultural field lacks adequate buffer	Streamside plantings, plant away from channel – river is widening	Moderate Priority	Improved habitat and water quality	Cost of plantings	Landowner, Windham County NRCD, WRC, CRWC, VCF, VANR, Town of Wilmington CREP, TFS, WHIP

Map 3: Impacts and Potential Projects Reaches T2.04-B through T2.05 North Branch of the Deerfield River

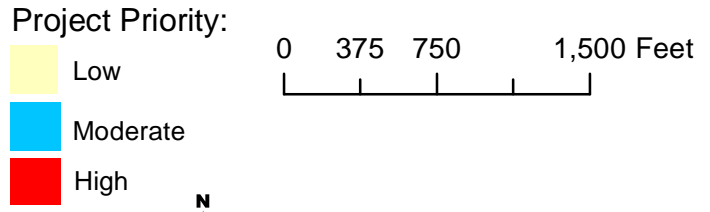


Legend

- X Cross Section Location
- ▬ Grade Control, Ledge
- ⚡ Channel Avulsion
- ⌒ Flood Chute
- Reach Point
- Segment Point
- ▬ Phase 2 Study Area
- ▬ Phase 1 Only
- ▬ Armoring
- Buffer Less Than 25 Feet
- ▬ Erosion
- ▬ Mass Failure
- ▬ Major Roads
- ▬ River Corridor Easement
- ▬ Draft FEH Zone 052213
- ▬ River Valley
- ▬ Wilmington Corridor Parcels
- ▬ Town Boundary
- ▬ Public Lands



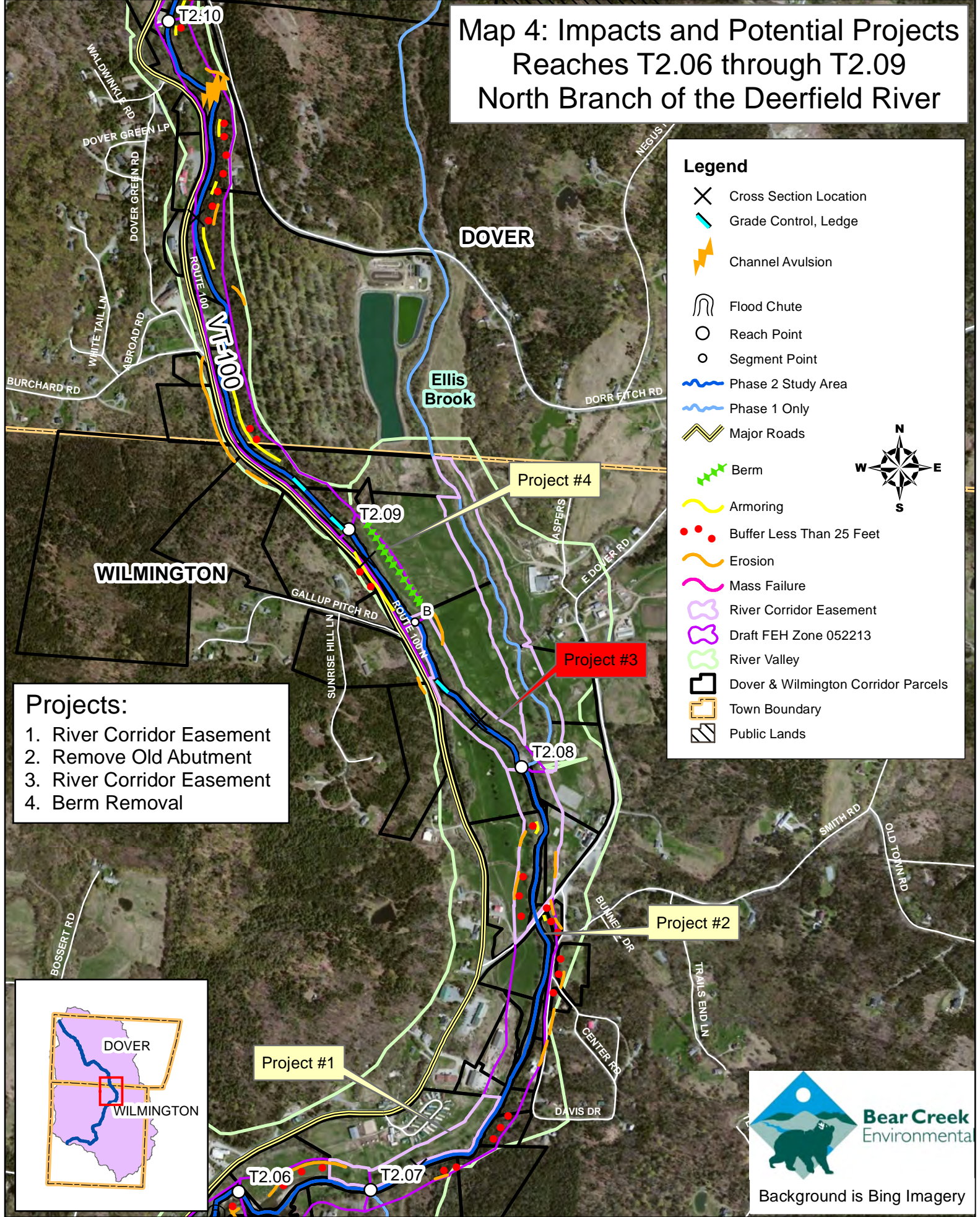
- Projects:**
1. River Corridor Easement
 2. Streamside Plantings



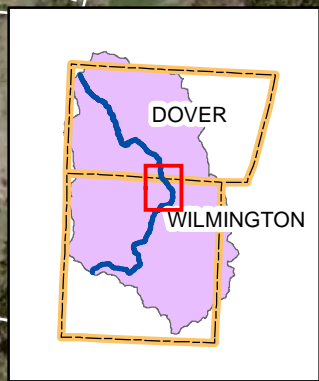
**Table 3. North Branch of the Deerfield River Main Stem
Map 3: T2.04-B through T2.05
Site Level Opportunities for Restoration and Protection
Wilmington, Vermont**

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Potential Partners/Programs
Project #1 T2.05	Passive Restoration	Channel has fair floodplain access along agricultural fields	Protect river through corridor easement	High Priority	Flood resiliency; improved habitat, water quality, and geomorphic stability	Cost of easement	Landowners, WRC, VANR, Town of Wilmington RCE
Project #2 T2.05	Passive Restoration	Area along western bank that lacks adequate buffer	Streamside plantings, plant away from channel – river is widening	Moderate Priority	Improved habitat and water quality	Cost of plantings	Landowners, Windham County NRCD, WRC, CRWC, VCF, VANR, Town of Wilmington CREP, TFS, WHIP

Map 4: Impacts and Potential Projects Reaches T2.06 through T2.09 North Branch of the Deerfield River



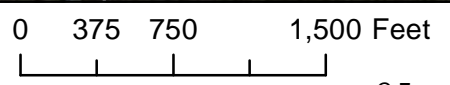
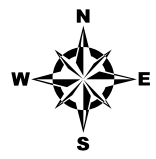
- Projects:**
1. River Corridor Easement
 2. Remove Old Abutment
 3. River Corridor Easement
 4. Berm Removal



Project Priority: Low Moderate High

Legend

- Cross Section Location
- Grade Control, Ledge
- Channel Avulsion
- Flood Chute
- Reach Point
- Segment Point
- Phase 2 Study Area
- Phase 1 Only
- Major Roads
- Berm
- Armoring
- Buffer Less Than 25 Feet
- Erosion
- Mass Failure
- River Corridor Easement
- Draft FEH Zone 052213
- River Valley
- Dover & Wilmington Corridor Parcels
- Town Boundary
- Public Lands

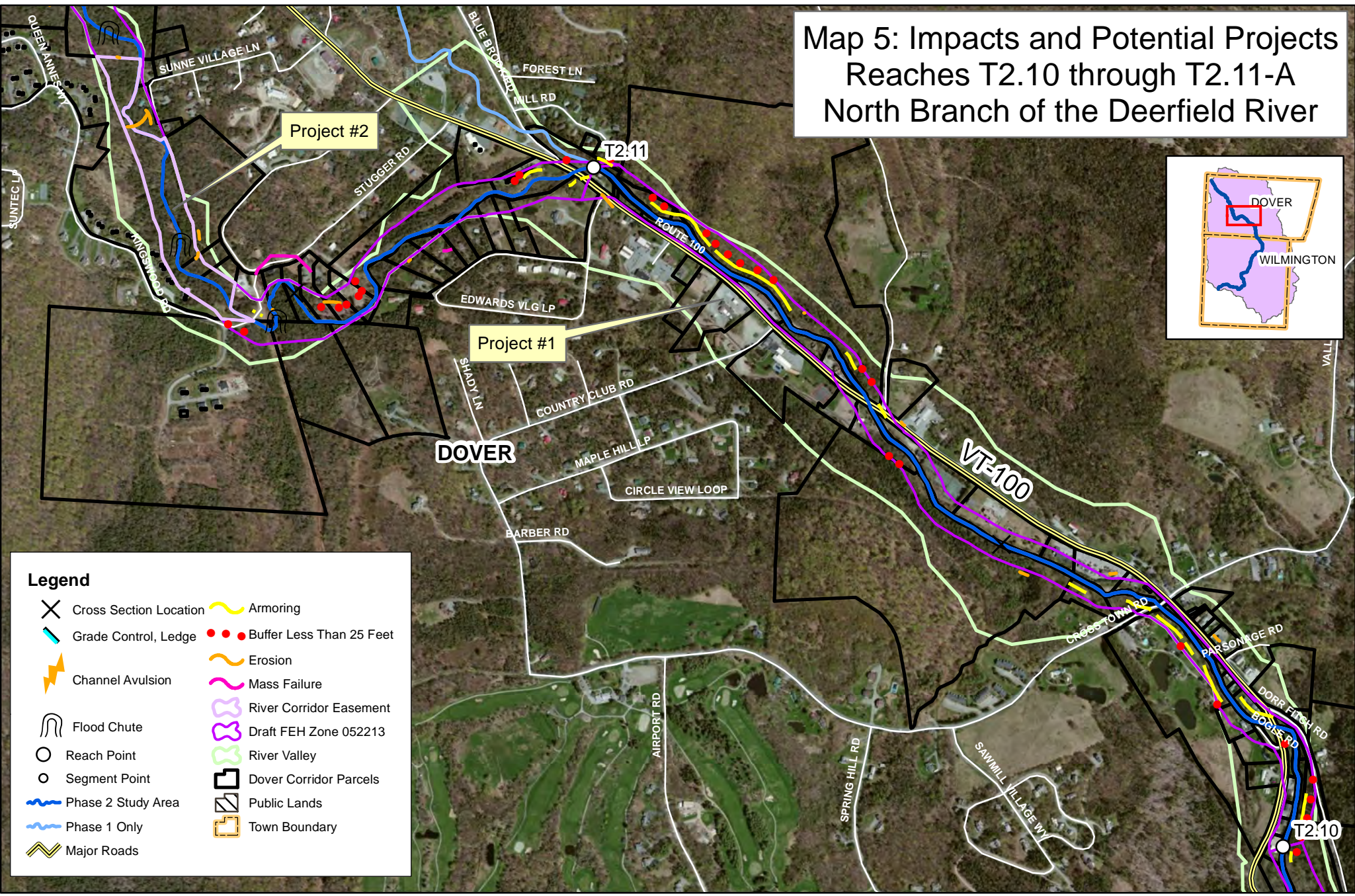
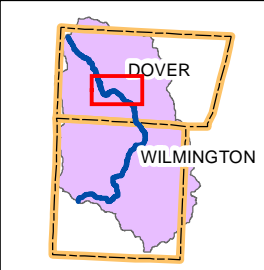


Background is Bing Imagery

**Table 4. North Branch of the Deerfield River Main Stem
Map 4: T2.06 through T2.09
Site Level Opportunities for Restoration and Protection
Wilmington and Dover, Vermont**

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Potential Partners/Programs
Project #1 T2.06 & T2.07	Passive Restoration	Northern river corridor, majority of channel has poor floodplain access	Protect river through corridor easement	Low Priority	Flood resiliency; improved habitat, water quality, and geomorphic stability	Cost of easement	Landowners, WRC, VANR, Town of Wilmington RCE
Project #2 T2.07	Active Restoration	An old abutment is noted on field map, is not a channel constriction. The abutment is currently deteriorating on its own. The bank where the abutment is located is steep and would need to be stabilized if the abutment were to be removed.	Remove old abutment	Low Priority	NA	NA	Landowner, WRC, VANR, Town of Wilmington
Project #3 T2.07 & T2.08-A	Passive Restoration	River corridor has fair to good floodplain access; proposed easement expanded to include the tributary, Ellis Brook	Protect river corridor through easement	High Priority	Flood resiliency; improved habitat, water quality, and geomorphic stability	Cost of easement	Landowners, WRC, VANR, Town of Wilmington RCE
Project #4 T2.08-B	Active Restoration	A 900-foot long berm along the eastern bank is restricting floodplain access. Berm is preventing flooding of North Branch Fire District #1 spray disposal field. Recent site visit (May 2013) revealed that there is floodplain access upstream and downstream of the berm.	Berm removal	Low Priority (likely conflicts with land use, floodplain access above and below)	Improved geomorphic stability	Cost of berm removal	Landowners, WRC, CRWC, VCF, VANR, Town of Wilmington ERP

Map 5: Impacts and Potential Projects Reaches T2.10 through T2.11-A North Branch of the Deerfield River



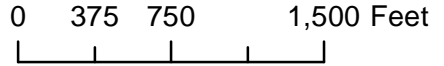
Legend

	Cross Section Location		Armoring
	Grade Control, Ledge		Buffer Less Than 25 Feet
	Channel Avulsion		Erosion
	Flood Chute		Mass Failure
	Reach Point		River Corridor Easement
	Segment Point		Draft FEH Zone 052213
	Phase 2 Study Area		River Valley
	Phase 1 Only		Dover Corridor Parcels
	Major Roads		Public Lands
			Town Boundary

- Projects:**
1. Stormwater Management
 2. River Corridor Easement

Project Priority:

- Low
- Moderate
- High

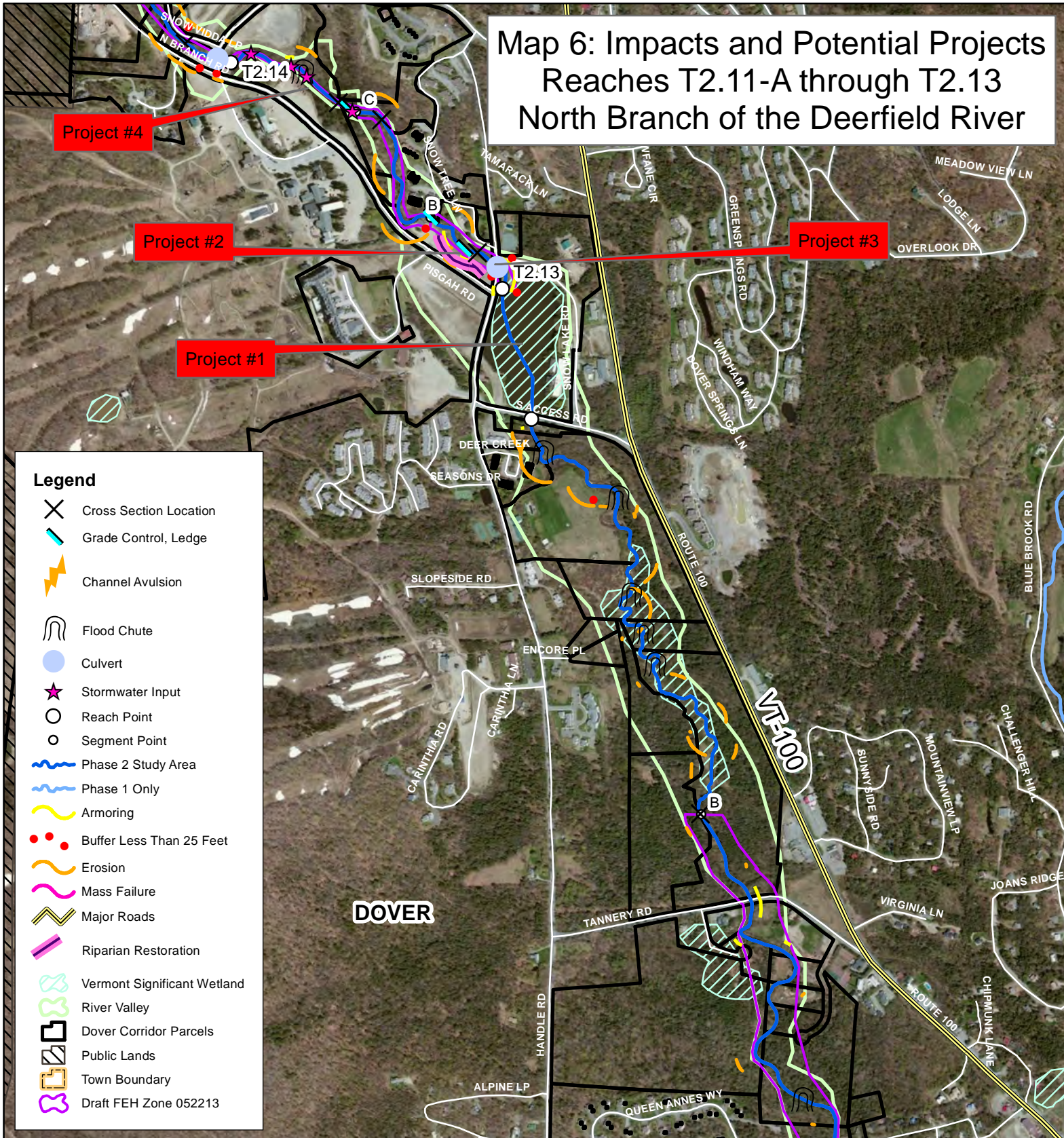


Background is Bing Imagery

**Table 5. North Branch of the Deerfield River Main Stem
Map 5: T2.10 through T2.11-A (lower section)
Site Level Opportunities for Restoration and Protection
Dover, Vermont**

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Potential Partners/Programs
Project #1 T2.10	Stormwater Management	Multiple stormwater inputs were identified along the stream channel in central Dover	Evaluate stormwater management practices	Low Priority	Improved water quality	Unknown	Landowners, WRC, VANR, Town of Dover ERP
Project #2 T2.11-A	Passive Restoration	Forested area with poor floodplain access	Protect river through corridor easement	Low Priority	Flood resiliency; improved habitat, water quality, and geomorphic stability	Cost of easement	Landowners, WRC, VANR, Town of Dover RCE

Map 6: Impacts and Potential Projects Reaches T2.11-A through T2.13 North Branch of the Deerfield River



Legend

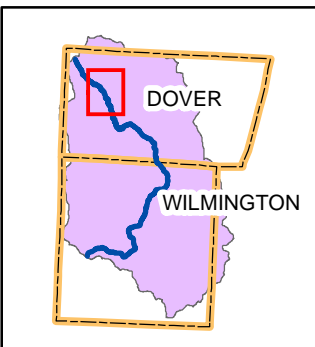
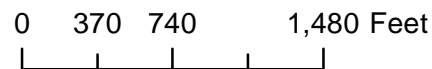
- Cross Section Location
- Grade Control, Ledge
- Channel Avulsion
- Flood Chute
- Culvert
- Stormwater Input
- Reach Point
- Segment Point
- Phase 2 Study Area
- Phase 1 Only
- Armoring
- Buffer Less Than 25 Feet
- Erosion
- Mass Failure
- Major Roads
- Riparian Restoration
- Vermont Significant Wetland
- River Valley
- Dover Corridor Parcels
- Public Lands
- Town Boundary
- Draft FEH Zone 052213

Projects:

1. Reestablish Natural Channel
2. Riparian Restoration
3. Investigate Culvert Replacement
4. Stormwater Management

Project Priority:

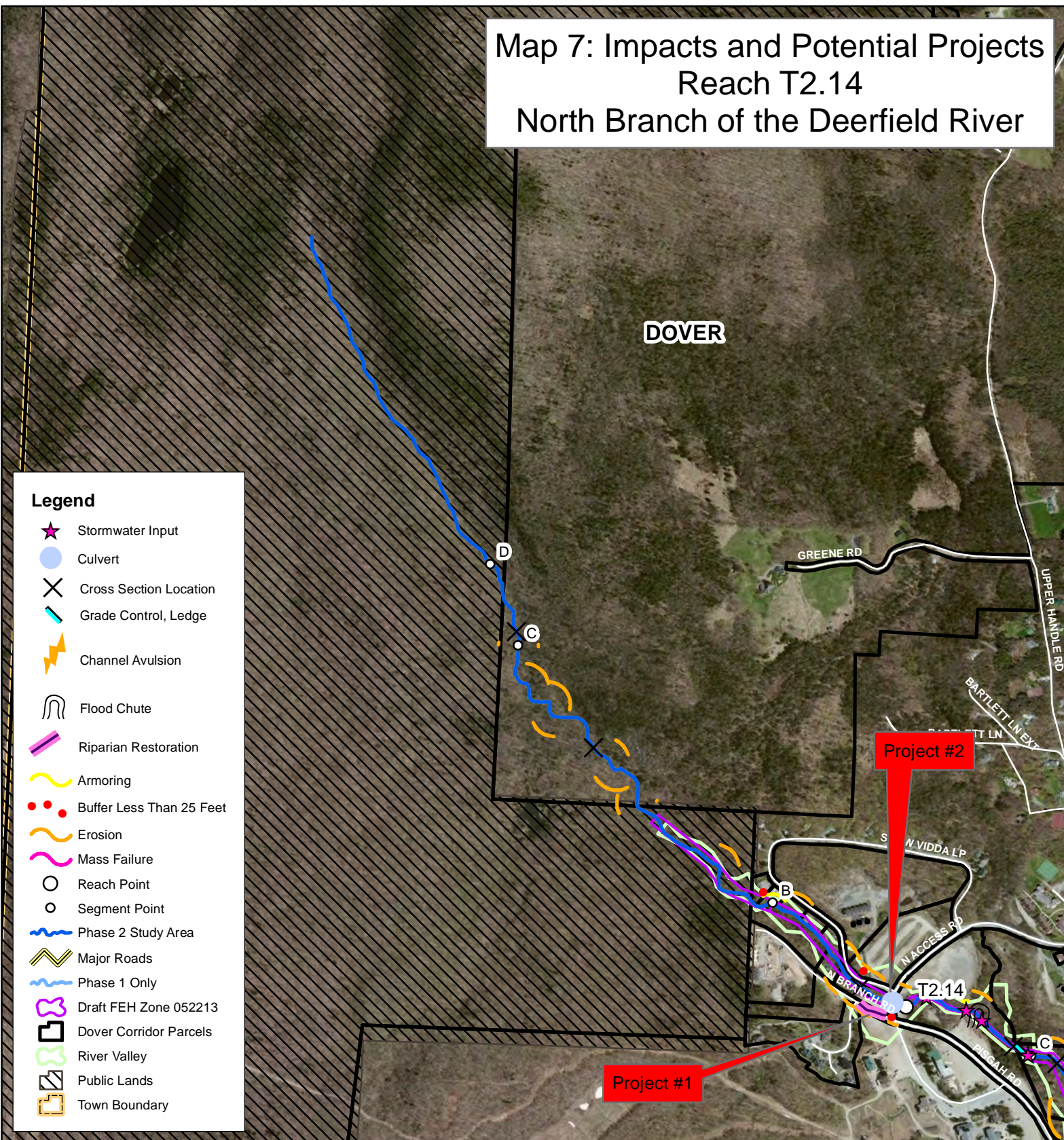
- Low
- Moderate
- High



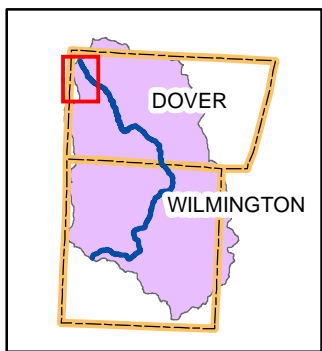
**Table 6. North Branch of the Deerfield River Main Stem
Map 6: T2.11-A (upper section) through T2.13
Site Level Opportunities for Restoration and Protection
Dover, Vermont**

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Potential Partners/Programs
Project #1 T2.12	Active Restoration	Snow Lake impoundment is resulting in geomorphic instability in downstream segments	Reestablish natural channel	High Priority	Improved habitat, water quality, and geomorphic stability	High Cost	Landowner, WRC, CRWC, VCF, VANR, Town of Dover ERP
Project #2 T2.13-A	Active Restoration	Elevated floodplain along parking lot is limiting floodplain access	Riparian restoration (improve floodplain and stormwater management)	High Priority	Improved habitat, water quality, and geomorphic stability	Unknown	Landowners, WRC, CRWC, VCF, VANR, Town of Wilmington ERP
Project #3 T2.13-A	Active Restoration	The Handle Road culvert has a “mostly incompatible” geomorphic rating and is limiting all aquatic organism passage.	Investigate culvert replacement	High Priority	Improved habitat and geomorphic stability	Cost of culvert design and replacement	Landowners, WRC, CRWC, VANR, Town of Dover
Project #4 T2.13-C	Stormwater Management	Multiple stormwater inputs flowing down from parking lot, observed in 2005 and 2012. Filling in pools with sediment	Evaluate stormwater management practices	High Priority	Improved water quality	Unknown	Landowners, WRC, VANR, Town of Dover ERP

Map 7: Impacts and Potential Projects Reach T2.14 North Branch of the Deerfield River



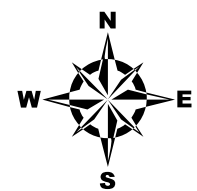
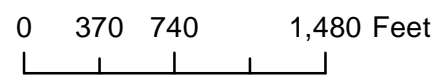
- Legend**
- ★ Stormwater Input
 - Culvert
 - ✕ Cross Section Location
 - ▬ Grade Control, Ledge
 - ⚡ Channel Avulsion
 - ⌒ Flood Chute
 - ▬ Riparian Restoration
 - ⤿ Armoring
 - Buffer Less Than 25 Feet
 - ⤿ Erosion
 - ⤿ Mass Failure
 - Reach Point
 - Segment Point
 - ▬ Phase 2 Study Area
 - ▬ Major Roads
 - ▬ Phase 1 Only
 - ⬭ Draft FEH Zone 052213
 - ▭ Dover Corridor Parcels
 - ▭ River Valley
 - ▭ Public Lands
 - ▭ Town Boundary



- Projects:**
1. Riparian Restoration
 2. Investigate Culvert Replacement

Project Priority:

- Low
- Moderate
- High



Background is Bing Imagery
C-13

**Table 7. North Branch of the Deerfield River Main Stem
Map 7: T2.14
Site Level Opportunities for Restoration and Protection
Dover, Vermont**

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Potential Partners/Programs
Project #1 T2.14-A	Active Restoration	Southern bank adjacent to parking has no buffer and receives runoff from parking area.	Riparian restoration (improve floodplain and stormwater management)	High Priority	Improved habitat, water quality, and geomorphic stability	Unknown	Landowner, WRC, CRWC, VCF, VANR, Town of Dover ERP, WHIP
Project #2 T2.14-A	Active Restoration	The North Access Road culvert has an AOP rating of “No AOP except adult salmonids” and is causing upstream deposition that may lead to further problems	Investigate culvert replacement	High Priority	Improved habitat and geomorphic stability	Cost of culvert design and replacement	Landowners, WRC, CRWC, VANR, Town of Dover